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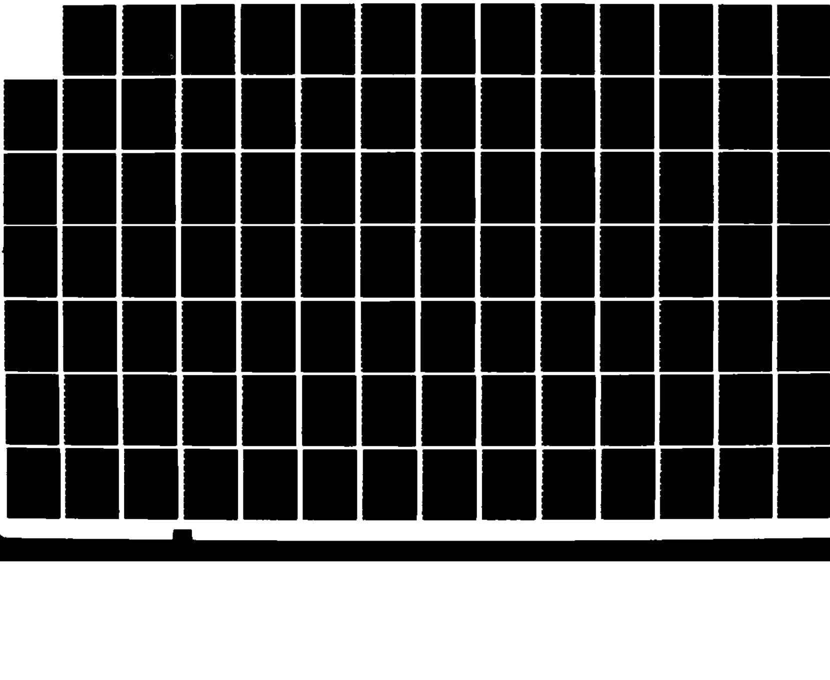

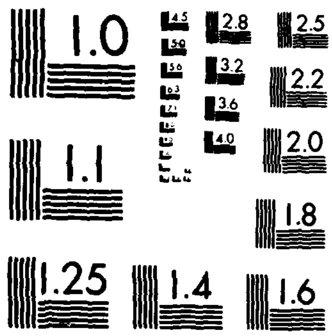

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INVESTIGATION OF AIR FORCE

BUILT-UP ROOFING TOLERANCES

THESIS

Dale R. Lavigne, B.S.
Captain, USAF

AFIT/GEM/DET/86S-16

DEPARTMENT OF THE AIR FORCE
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INVESTIGATION OF AIR FORCE BUILT-UP ROOFING TOLERANCES

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

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Master of Science in Engineering Management

Dale R. Lavigne, B.S.

Captain, USAF

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Abstract

The level of construction quality required by Air Force Manual (AFM) 91-36, Built-Up Roof Management Program, is controversial. The objective of this research is to provide information pertaining to the need for and obtainability of this quality. This is done by combining a descriptive study and a statistical analysis of historical data.

The descriptive study provides a general review of published knowledge pertaining to the use and need for built-up roofing tolerances. The study draws from formal research, international symposiums, published information from national associations, periodicals and journals, texts, government publications, and manufacturers' literature. Factors influencing performance are presented. One factor, workmanship, is especially highlighted. System performance attributes are also discussed. Although vast improvement has been realized over the past ten years, premature failure rates of 10 to 15 percent are recorded. To assist in showing the need for tolerances the main built-up roofing problems, which could create failure situations, are introduced. Finally, the study provides existing viewpoints on the use of tolerances for indicating performance ability. Also included are currently recommended rates and tolerances.

The statistical analysis shows what tolerances have been obtained in completed Air Force roofing projects. Knowing what tolerances have been attained indicates what tolerances can be obtained. Results indicate large variability with a fairly low percentage of the samples meeting Air Force requirements.

The investigation shows the selection of realistic tolerances is difficult but their use is important. To ensure quality conformance, tolerances are recommended at levels lower than statistical analysis can justify. Continued research on performance requirements and statistical quality control is warranted.

INVESTIGATION OF AIR FORCE BUILT-UP ROOFING TOLERANCES

I. Introduction

Chapter Overview

Chapter I contains general background of the topic which led to this research concerning built-up roofing tolerances specified in Air Force construction contracts. In addition, the research problem statement, the research questions, and the scope and limitations of the research are presented.

General Issue

In 1980, the Department of the Air Force published Air F-- e Manual (AFM) 91-36, Built-up Roof Management Program (22). AFM 91-36 was developed to improve the performance of built-u. roof systems within the Air Force inventory. Chapters 5 and 6 of the manual were designed to assist the Air Force in developing and managing built-up roofing construction contracts. This portion of the manual is continuously being reviewed and evaluated for possible improvements. Areas of concern within the manual are normally identified by the base roofing engineer; however, the roofing industry, for instance the National Roofing Contractors Association (NRCA) and Asphalt Roofing Manufacturers Association (ARMA), has also expressed its concern for changes. One area of increasing concern is the allowable tolerances, or range of acceptable variances.

In the August 1985 publication of Roofing Spec magazine, the NRCA introduced a document entitled Quality Control in the Application of Built-Up Roofing (26). This document addresses the areas of workmanship, test cuts, and the examination of built-up roof construction. The allowable variances identified in this document differ from those established in AFM 91-36. Any difference must be researched to allow the Air Force Engineering and Services Center (AFESC) at Tyndall AFB, Florida, to make further decisions which will impact Air Force built-up roofing performance.

Background

Introduction. Built-up roofing has been used in various forms since 1844 (64:2) and in its present form for more than fifty years. The built-up roof membrane, or weatherproofing component of the system, is described by C.W. Griffin as a composition of roofing felts and bitumen combined into a laminate, usually surfaced with aggregate embedded in a bituminous top or "flood" coat. Bitumen, a generic term for coal tar and asphalt, is the waterproofing agent and most important membrane element (34:127).

According to technical report M-334, Evaluation of Contractor Quality Control of Built-Up Roofing, by the U.S. Army Construction Engineering Research Laboratory, four-ply built-up roofing installed before the late 1960's, in accordance with Corp of Engineer Guide Specifications, could be expected to have a service life of 20 years or more (76:7). The Air Force used these guide specifications prior

to implementation of currently approved specifications. The service life of Air Force roofs should, therefore, have been 20 years. Studies conducted by the Air Force and the Naval Construction Battalion Center however, have shown that an average service life of 12 years might be expected (75:5). A recent report by Captain Suzanne Santos of the Air Force Institute of Technology, School of Civil Engineering, stated a Strategic Air Command study showed the Air Force was losing 160 million dollars over the life cycle of roofs due to premature failure (62:6). The Air Force began an extensive investigation to improve the quality of built-up roofs installed by contract. The Strategic Air Command and Construction Consultants Incorporated of Detroit, Michigan developed a program which later lead to the implementation of Air Force Manual (AFM) 91-36, Built-Up Roof Management Program, by the entire Air Force.

AFM 91-36 is a real property operation and maintenance manual for built-up roofs which includes design and construction management information for roofing contracts. This portion of the manual has been met with controversy. At the 1985 International Symposium on Roofing Technology, the controversy was identified by William C. Cullen of the National Roofing Contractors Association (NRCA).

> The quality control portion of the USAF roof management program has several controversial issues which should be addressed and clarified. These involve the USAF definition of what I believe to be unreasonable application tolerances [19:47].

Tolerance, as used in built-up roofing, is an allowable variation from the standard (82:2661). The standard is

stipulated in the contract specifications. Air Force tolerances were also addressed in a technical report by an NRCA Task Force on Air Force Manual Revisions. It stated that some of the Air Force tolerances may be too strict, while others may not be strict enough, to obtain acceptable performance of built-up roof systems (8:29).

The NRCA has published a booklet concerning quality control of built-up roofing. The booklet, Quality Control in the Application of Built-Up Roofing, was introduced in an article by Rob Eiseman. The article appeared in the August 1985 publication of Roofing Spec magazine and is entitled "NRCA calls Quality Control Ultimate Built-Up Roofing Tool." The booklet, according to the NRCA, is based on industry literature, test results, research papers, and association documents (58:2). NRCA Executive Vice President Fred Good says, "Our goal is to create a reference that all parties involved in the roofing process can use to agree on sound application methods and allowable variances" (26:23). Eiseman states the origin of this booklet can be traced back to work completed by the Strategic Air Command in 1976. Again Eiseman addresses AFM 91-36 in the article when he states, "The document's specification was, in many cases, impossible to maintain" [26:23].

The Asphalt Roofing Manufacturers Association (ARMA) is also developing a built-up roofing systems design guide. A 1984 proposal for this document stated that it would define a quality built-up roof system; discuss a goal of zero defects; present performance criteria with a focus on longevity,

serviceability, and durability; and provide application tolerances (2:27). The ARMA document is in draft form with review to be completed in August 1986 (3; 65).

Roofing Performance. Within the design, construction, and maintenance process of built-up roofing there are many factors which can impact on the service life of the system. Even when only considering the construction phase, or application, of a built-up roof system there are numerous variables which impact the overall performance of the system. It is important to have some understanding of these factors and variables in the study of quality conformance in built-up roofing.

Factors. In addition to military reports stating the extent of premature roof failures, the National Bureau of Standards has published study results. The National Bureau of Standards has found 10 to 15 percent of the built-up roofs, installed annually, fail prematurely (14). John A. Watson in his text, *Commercial Roofing Systems*, indicates a failure rate of 4 to 5 percent but takes no responsibility for accuracy of these figures (74). Many factors contribute to these failures and the overall performance of roofs. The NRCA lists the following general factors in *Quality Control in the Application of Built-Up Roofing* (58:2).

1. Building design
2. Substrate suitability
3. Application Procedures
4. Quality of workmanship
5. Suitability of materials

6. Suitability of specifications

7. Slope for drainage

8. Storage and handling of materials

9. Conditions roof subjected to after installation

The Army Construction Engineering Research Laboratory identified the following as major performance factors at Army installations (75:5).

1. Quality of workmanship

2. Quality of manufactured materials

3. Design

4. Deadlines

5. Incompatibilities in drawings and specifications

6. Ambiguities in specifications

7. Lack of maintenance

The NRCA identifies several essential elements to improve roof performance. These elements are as follows (19:46):

1. Adequate material standards.

2. Design and application specifications commensurate with strength, safety, and durability of the roofing system.

3. Quality control to bring the roofing system into conformance with established requirements.

One item appearing consistently when listing factors that impact roofing performance is quality. There are two kinds of quality which influence roof performance; design quality and quality conformance (35:18). The major controversy over AFM 91-36 is concerned with quality conformance; the ability of contractors to conform to specified requiremeats.

Application. Before quality conformance can be discussed, one must begin to understand some elements influencing the built-up roof application process. William J. DeBarry, Vice President Testing Engineers of San Diego, summarizes this influence when stating in an article on quality built-up roofing that application is subject to many variables (21:28). The NRCA quality control booklet lists these variables to show built-up roofing is an art more than a scientific process. These variables include temperature, weather, job-site conditions, material combinations, penetration details, and perimeter details (58:1).

AFM 91-36 addresses many of these variables hoping to reduce the possible impact of these variables on the application process. For instance, the manual's master specification includes the statement that roofing application should not proceed during inclement weather unless the work being accomplished is temporary (22:5-29, 5-50). Another example is that a certification from the built-up roofing system manufacturer is required to ensure material combinations are suitable for the project (22:5-18). The influence of penetration and perimeter details on roofing performance is summarized by Maxwell C. Baker in Roofs:

> The terminations of a roofing membrane sometimes create conditions where perfection of detail and workmanship may be difficult to achieve in producing the flashings. Even if perfection of detail is achieved in all aspects of the flashings during construction, subsequent inevitable building and membrane movement as well as weathering will likely produce imperfections [7:246].

This influence of penetration and perimeter details is reduced by allowing the contractor to recommend changes during the required preconstruction conference or at any time during the contract (22:5-15, 6-2).

Conformance. Quality conformance in built-up roofing is a difficult task. Application variables are numerous and have to be controlled. In addition, no one individual or group has complete control over the constructed roofing system. Those involved in the process to obtain a quality product include the user, the designer, possibly a general contractor, the roofing contractor, material manufacturers, the inspection force, and even the decking installers (75:5). Unsatisfactory performance by any one of these individuals will reduce the overall performance of the built-up roofing system. Responsibility must be shared by all. The subject of responsibility was one topic of Architectural Record's 31st round table brought together to discuss roofing problems. Architect Michael Gordon from Environetics International of New York City states that a chain of responsibility, starting with the design and ending with the installation of the roof, is required (61:147). Ensuring each link in the chain performs satisfactory, therefore producing a quality product, is the purpose of the Air Force quality assurance program.

Quality Assurance. William C. Cullen defines quality assurance as a systematic plan of actions required to provide adequate confidence that quality conformance is met (19:46). AFM 91-36 defines quality assurance in a similar fashion;

activities providing assurance that overall quality control is effective (22:1-4). Tasks included in verifying and documenting satisfactory completion of the work is usually identified by a system of checks, audits, inspections, and other verification methods (33:7). Although AFM 91-36 addresses all aspects of quality assurance from design to contract completion, only quality control and sample testing will be discussed in this investigation. These are the controversial aspects of the Air Force program previously identified.

Quality Control. William C. Cullen identifies quality control as the implementation of the quality assurance plan (19:46). Victor J. Goetz (33:6) and AFM 91-36 (22:5-14) define it as the process which maintains the actual product quality within specified ranges of value. In labor intensive activities, such as built-up roof construction, it is generally understood that errors will be made (52:14). The quality control system identified in AFM 91-36 is designed to detect errors so corrective actions may be taken.

Factors involved in the level of quality control obtained include the following (29:20):

1. Men
2. Money
3. Management
4. Materials
5. Methods

Under AFM 91-36, quality control is conducted by the contractor and verified by government audit and inspection.

The contractor is held responsible to comply with standards and eliminate negative effects of the above factors. The contractor selects the quality controller, estimates costs of quality control to be included in the bid for the contract, and manages the program. Vital to quality control, the quality controller selected by the contractor must have the ability to recognize deviations from specified requirements and be willing and able to enforce these requirements (76:26).

Inspection and Testing. As required by AFM 91-36, inspection is conducted by government personnel. Inspection of built-up roof installation includes visual examination and sample analysis. Inspection is a critical part of the quality assurance process providing information pertaining to one of the most important roof performance factors -- workmanship (36:9). Full time inspection can improve the quality, and therefore performance, of the roof even though it is not the entire solution to premature roof failures (75:12).

Visual inspection is accepted as being vital. Michael Dhunjishah of the Houston, Texas, Law Engineering Testing Company, identifies visual inspection as the best method to evaluate built-up roofing (23:27). The following statement from the NRCA quality control booklet agrees: "The most effective means to evaluate quality installation is by thorough, continuous visual examination at the time of application" (2:3). Agreement like this, however, does not occur with sample analysis. The Air Force sample analysis

can be pinpointed as the two most controversial aspects of AFM 91-36.

Two major positions exist when built-up roof testing is discussed. The first position is depicted by the NRCA booklet Quality Control in the Application of Built-Up Roofing. The booklet states, "Roof cuts [required by testing] are an unrealistic basis for drawing conclusions about an entire roof and do not address many factors that are critical to obtaining watertight integrity" (58:10). In addition to the idea that all factors are not addressed, the booklet adds that available testing methods can be misleading because tests in general are scientific but application procedures are not (58:1,10). Robert E. First adds to this position in an article about test cuts:

> Since roofing materials are not applied with measuring devices to ensure equal distribution at all points of the roof, it is wrong to carefully weigh and measure the thickness of layers in a test cut and make decisions about the quality of a roof [30:13].

In summary, the first position on testing roofs is that the samples taken are not representative of the entire roof, that data is not available to support the idea behind the testing of roofs by analyzing test cuts, and that visual inspection is preferred. Rob Eiseman adds that the precision and accuracy of the test method employed by the Air Force have not been established (26:25).

The second position does not imply that test cuts account for all factors involved in a quality roofing system but can be used as a valuable supplement to other quality

assurance techniques (14). AFM 91-36 states that sampling and analysis is an important tool of quality assurance (22:6-5). In the article "NRCA Calls Quality Control Ultimate Built-Up Roofing Tool," David Richards, manager of technical services in Owens-Corning Fiberglass Corporation Commercial Roofing Division, was quoted on the idea of testing. This quotation summarizes the second position regarding testing built-up roofing:

> We believe cutouts are important factors in assisting us in evaluating built-up roofing applications as a supplement to visual audits. Cutouts have always been an effective means for helping us determine whether or not our materials have been applied correctly. We are not saying that this is a substitute for visual inspection by any means, but you don't simply take 25 years of a proven testing method and disregard it as no longer valid [26:25].

Tolerances. The goal of tolerances specified in AFM 91-36 is to control workmanship. This control of contractor workmanship is essential to ensure satisfactory roof performance. Roofing consultant Werner Gumpertz, of Simpson, Gumpertz & Heyer, estimates that 75 to 80 percent of roofing failures can be attributed to workmanship (61:147).

Application criteria will assist in insuring quality workmanship if they are reasonable (26:269). Victor Goetz expands this when he states, "If the product is over-engineered so that stated tolerances cannot routinely be obtained, there will be great difficulty in attempting to control quality" (33:7). Although Goetz was referring to a manufactured product, the statement can be applied to built-up roof construction. Revised with roofing terms the

statement would read: If specified tolerances can not be routinely obtained, because of the various application variables, then quality conformance will be difficult.

Jack Williams, of Twin City Roofing Inc., uses the phrase "level of preciseness" to represent the variations inherent in accepted methods of built-up roof application (83:34). Using this phrase, the controversy pertaining to tolerances specified in AFM 91-36 is that these tolerances do not account for the existing "level of preciseness."

Summary

To improve the performance of Air Force built-up roofs to an acceptable level, a built-up roof management program was intitiated. The program is based on AFM 91-36. Many factors of the design-construction-maintenance process affect roofing performance and are addressed by the Air Force manual. One of the most important factors is workmanship. The Air Force quality assurance process is designed to ensure satisfactory workmanship; satisfactory workmanship implying quality conformance. Current industry application procedures directly affect the ability of the contractor to produce a "quality product" or to conform to specified standards. This is the basis for one controversy concerning AFM 91-36. Are Air Force standards, or tolerances, appropriate to improve roofing performance? This investigation takes one step to resolve this controversy.

Problem Statement

The Air Force quality assurance process for built-up roof construction is governed by AFM 91-36. The process is based on the contractor's quality control, government inspectors' visual examination, government audit of quality control tasks, and daily sampling of the roof costruction for testing. The level of quality, or allowable standards, this process attempts to obtain is controversial. Organizations such as the National Roofing Contractors Association (NRCA) and the Asphalt Roofing Manufacturers Association (ARMA) have expressed concern over the level of quality which can be obtained in built-up roof construction (8;19;26).

Visual inspection is accepted as a proven practice to assist in obtaining conformance with application requirements. Testing of built-up roof samples, however, is not recognized by all as an applicable part of a quality assurance program (26;30;58). AFM 91-36 currently requires sample testing using American Society for Testing and Materials (ASTM) Standard D-2829, "Sampling and Analysis of Built-up Roofs."

The test sample results are compared to stated standards to ensure conformance with specified quality. The ranges of allowable variance for each measureable roofing characteristic vary and even the need for each standard is disputed. This research, therefore, will investigate the requirement for specifying tolerances and the Air Force allowable variances which are specified for applicable components of built-up roof construction.

Research Objective

The construction quality and performance life of built-up roofing systems are dependent on many factors throughout the design, construction, and maintenance process. Research is conducted worldwide on these factors. Some of the research in the United States is conducted by the National Roofing Contractors Association (NRCA), the Asphalt Roofing Manufacturers Association (ARMA), the National Bureau of Standards, the Army Corps of Engineers, universities, independent laboratories, and numerous roofing consultants. Even with organizations such as these conducting research daily, many questions still remain and no end to this research seems near.

No single researcher can answer all the questions or solve all the problems which exist. For this reason a researcher generally chooses one topic to investigate. This study also took this approach. The topic of concern herein is built-up roofing tolerances. More specifically, this study investigated the tolerances specified by Air Force Manual (AFM) 91-36. It is understood that all controversies surrounding the tolerances specified in AFM 91-36 are not solved by this one study. It does, however, take a step in that direction.

The objective of this research was to provide those individuals responsible for the Air Force built-up roof management program with information regarding AFM 91-36 roofing tolerances and built-up roofing tolerances in

general. The approach used in this study involved reviewing published literature related to built-up roofing tolerances and conducting a statistical analysis on existing Air Force built-up roof sample test results. It is the author's hope that the findings and results of this investigation will aid in future decisions regarding tolerances specified in Air Force built-up roof construction projects.

Research Questions

Questions answered by this investigation in order to fulfill the research objective follow:

1. For which aspects of built-up roofing applications does existing research and technology indicate that tolerances should be specified?

2. On what aspects of built-up roofing systems does the Air Force specify tolerances?

3. What built-up roofing tolerances are specified by Air Force built-up roof construction projects?

4. What built-up roofing tolerances are recommended by others?

5. Based on historical built-up roof sample test data, what variances are Air Force contracted roofing contractors obtaining on built-up roof construction projects?

Scope and Limitations

There are many factors which impact the overall performance of a built-up roof system. The scope of this investigation was limited to researching one area of only one such factor. The tolerances specified to measure contractor workmanship will be addressed.

Workmanship is influenced by several variables; e.g. materials, environmental conditions, available equipment and structural conditions. These variables were identified and discussed but were not extensively researched. The influence of these variables on workmanship, as controlled by AFM 91-36, were accepted as inherent in the process when analyzing available sample test results to discover the extent of compliance with specified tolerances.

The investigation researched the requirement for specific tolerances. There will be little attempt to discuss the various testing methods used to verify product quality or the controversy surrounding these tests.

II. Methodology

Chapter Overview

Research on built-up roofing tolerances could be conducted in several ways and investigate many concerns within each area. This chapter describes the methodology used to accomplish the research objective - Provide information regarding tolerances specified in AFM 91-36 to those individuals who are responsible for making decisions concerning the manual. This objective was met by answering the following research questions:

1. For which aspects of built-up roofing application does existing research and technology indicate that tolerances should be specified?

2. On what aspects of built-up roofing systems does the Air Force specify tolerances?

3. What built-up roofing tolerances are specified in Air Force built-up roof construction projects?

4. What built-up roofing tolerances are recommended by others?

5. Based on historical built-up roof sample test data, what variances are Air Force contracted roofing contractors obtaining on built-up roof construction projects?

To answer these research questions, this investigation combined a descriptive study with a statistical analysis of historical data.

Descriptive Study

This investigation regarding built-up roofing tolerances began with a descriptive study. The descriptive study provides a profile of existing knowledge pertaining to the

use and need for built-up roofing tolerances. Tolerances which are currently specified or recommended are also presented. In essence, research questions 1, 2, 3, and 4 were answered by the descriptive study.

Published sources of knowledge pertaining to built-up roofing tolerances vary considerably in their point-of-view, purpose, and information portrayed. The descriptive study drew from many of these sources including formal research, international symposiums on roofs and roofing, published information from national associations, endless periodicals and journals, government publications, texts, and manufacturers' literature. Countless articles and reports were reviewed and assimilated into the descriptive study. The assertion, however, can be made that other pertinent sources exist and were not incorporated into this investigation.

Statistical Analysis

The statistical analysis used in this investigation was designed to answer research question 5. Basically, the purpose of the statistical analysis is to provide an insight into what variances have resulted in past Air Force roofing projects.

Test Data. During the construction of built-up roofs, test samples are taken for laboratory analysis. Test samples were taken in accordance with AFM 91-36 and forwarded to a testing laboratory. For the statistical analysis portion of this investigation, the laboratory analysis results were collected, data extracted from the lab reports, and

statistical manipulations performed. Extracted data includes the following:

1. Required and actual interply bitumen weight.
2. Required and actual flood coat bitumen weight.
3. Required and actual total aggregate quantities.
4. Required and actual embedded aggregate quantities.
5. Required and actual headlap.

Test reports were obtained from three separate testing laboratories: Chicago Testing Laboratory, Inc.; Roof Engineering Inc.; and INSPEC, Inc. Reports for the years 1981 to 1985 were requested. The majority of the reports received were from 1982 to 1985. Actual quantities of reports used in the analysis are provided in Chapter IV and in the appendix.

Analysis. The roof sample test reports provide the required, or specified, and actual values for the bitumen weights, aggregate quantities, and headlap. The actual or test value, as used in this investigation, refers to the sample quantities determined from the American Society for Testing and Materials procedure. Results of the analysis included determination of mean variances, and maximum variances. On a recommendation by Jim Koontz, of Roof Engineering Inc., the average variances for values above and below specified quantities were determined. In addition, a frequency evaluation was completed to identify the sample percentage within various variance levels. The analysis was completed for each year from 1982 to 1985 for bitumen flood

and interply weights, total and embedded aggregate quantities, and headlap.

In this analysis to investigate variances, from specified values, obtained in Air Force built-up roofing projects, the Statistical Package for the Social Sciences (SPSS), available at the Air Force Institute of Technology, was used. A summary of this analysis is provided in Chapter IV with complete analysis results available in the appendicies.

III. Descriptive Study

Chapter Overview

At the onset of this research, the information to be included in the descriptive study was to be somewhat different than what it has evolved into. Originally, the study was to quantitatively justify the need for tolerances and identify what tolerances are being recommended by various associations, manufacturers, owners and researchers. There was no difficulty in locating tolerance recommendations but the need for these tolerances could not be quantitatively justified. Therefore, along with the viewpoints on and recommendations for tolerances, this descriptive study provides information on why tolerances may be needed. To do this the study identifies built-up roofing problems, their causes, and prevention; summarizes the role of various built-up roofing components; and discusses performance attributes and requirements. The descriptive study is not a comprehensive text on built-up roofing or a built-up roofing design guide. It is, however, a general review of published knowledge on built-up roofing topics relating directly or indirectly to tolerances. This review provides answers to research questions one to four developed in Chapter I and discussed in Chapter II.

Study Introduction

In Chapter I, typical factors which contribute to the construction quality of a built-up roofing system were introduced. Predominately discussed factors include the structure, application procedures, workmanship, design, and materials. Recall that quality control is the measuring of quality conformance and the action taken on any intolerable differences found (43:3). Quality control of built-up roof construction can not improve the structure or design quality but can influence other factors which influence product quality including human error, inadequate materials, and insufficient equipment and tools (69:679). Intuitively then, to reduce negative influences of these factors the application process and the material quality are controlled (69:680). One other way to influence product quality is by controlling the outgoing product (69:680). This being done by sampling the product and making alterations where necessary. Material quality and the application process, then, will be discussed throughout this study in an attempt to show how they influence built-up roof construction and therefore the ability to or not to attain specified tolerances upon sampling.

Built-Up Roofing Components

When discussing built-up roof tolerances an understanding of the major system components, their role, and potential material quality problems are required. Only the main components; surfacing, bitumen, and felts; will be presented.

Surfacing. The surfacing placed on hot-applied built-up roofs varies depending on several factors including environmental conditions, facility purpose, aesthetic desires, and costs. The most common types of surfacing include mineral aggregate, asphalt (hot or cold), mineral-surfaced cap sheet, and heat relective coatings (34:141). Air Force roofs typically receive a mineral aggregate surface treatment. For this reason and since extensive research has been conducted and is available for review on mineral aggregate, this study concentrates on aggregate sufacing.

The National Roofing Contractors Association (NRCA) Roofing & Waterproofing Manual lists various materials used for surface aggregates including gravel, slag, and marble chips, but leaves it open to others (57:26). The aggregate, no matter which acceptable material is selected, serves a valuable function. There are several advantages or benefits obtained from aggregate surfacing. The most common advantages cited include protection from the elements, fire protection, and reduced system temperatures. A more complete listing, from various sources (72:1; 53:2; 47:12; 58:9; 56:13; 12:21; 34:127, 144) follows.

1. Protection from solar radiation and photochemical oxidation of bitumen
2. Protection from wind, rain and foot traffic
3. Fire hazard reduction
4. Corrosion resistance in industrial areas
5. Wind-uplift resistance
6. Surface temperature reduction
7. Damming action permits heavy application of bitumen
8. Reduces seasonal range of temperatures
9. Even flow of water to drains

These advantages are summarized in several sources (38:777; 20:38; 7:38) stating that aggregate can improve the durability of the roofing membrane. For instance Canadian Building Digest 65 includes the following:

> By protecting the bitumens from the ultraviolet rays of the sun, abrasion from wind and rain, and casual light foot traffic, such surfacing can substantially extend the life of bituminous roofs [72:4].

Various disadvantages to the use of aggregate surfacing have been raised. These include increasing the dead weight, making defects difficult to locate, and increased difficulty in making roof repairs and replacements (72:4; 34:145). Using aggregate also creates a potential problem when it is wet. Wet aggregate can cause bubbles in the bitumen and in severe cases penetrate and wet underlying felts (7:297). Finally, aggregate can promote slippage.

Aggregate quantities recommended are typically 400 pounds per 100 square feet for gravel and 300 pounds for slag. Robert A. LaCosse, however, in an article on aggregates states the <u>NRCA Roofing & Waterproofing Manual</u> suggests a gravel surface rate of 500 pounds per 100 square feet (50:36). In addition, several manufacturers of built-up roofing products word the 400 and 300 pound requirements slightly different. For instance, Manville requires "approximately" 400 and 300 pounds per 100 square feet (55:23-24), while Koppers recommends "not less than" these quantities (47:13+). The National Bureau of Standards (NBS) Technical Note 965 discusses aggregate quantities and sizing when it

suggests a heavy layer of larger, uniformly graded aggregate will provide more protection than a thin layer of small aggregate (77:7). Proper sizing can also prevent gravel movement (7:297).

Embedment of aggregate is required by Air Force Manual (AFM) 91-36. Reasons for requiring embedment, such as stabilizing the bitumen flood coat, were alluded to when the disadvantages were presented. Maxwell Baker, in his book entitled Roofs, states the following about embedment:

> Embedment is a secondary and separate function from waterproofing. The aggregate is applied to protect and maintain the top coating of bitumen. It just happens to be a convienient practice to embed the gravel to help keep it from washing or blowing away [7:297].

Some of the manufacturers requiring embedment include Manville (55:23-24), Koppers (47:11), Genstar (32:7), and Owens-Corning (59:15). The NRCA Roofing & Waterproofing Manual also states that the aggregate should be set in bitumen (50:26).

Felts. Roofing felt is a mat of organic or inorganic fibres (81:213). There are various types of felts. Felts can be saturated or impregnated with bitumen or they may be untreated. A partial list of the various felt types follows (81:24; 22:2-4, 2-5).

1. Asphalt-Saturated Organic Felt
2. Coal-Tar Saturated Organic Felt
3. Asphalt-Saturated Asbestos Felt
4. Asphalt-Impregnated Glass Mat
5. Mineral-Surfaced Felt
6. Asphalt Treated Glass Fabric
7. Coal Tar Treated Glass Fabric
8. Reinforced Base Flashing

The felt in a built-up roofing system serves important functions. In general, it prevents rupture of the roofing membrane, prevents flow of bitumen, strengthens the roof covering, enables several thin layers of bitumen to be applied, and protects the bitumen from water degradation (6:2; 56:12).

Bitumen. Bitumen is identified as the most important element in built-up roofing systems. It plays a dual role serving as the waterproofing material and adhesive for the system (24:120). Typical tolerances specified on the bitumen are for interply and flood coat application rates. The importance of surface bitumen, as compared to interply bitumen, is disucssed when C. W. Griffin wrote the following in the *Manual of Built-Up Roof Systems*:

> The flood coats major purpose is to bond the aggregate to the membrane. It does provide some additional waterproofing, but it cannot function as the principle waterproofing agent because its film can be broken [34:150].

There are two common hot-applied bitumen products - asphalt and coal tar. Asphalt is a product of petroleum distillation. It receives some refinement to achieve desireable properties and softening points (6:1). Coal tar is a material derived from coking coal (22:A1-2). The use of coal tar was once more popular than it is today. Current estimates of coal tar use in built-up roofing is between five and eight percent (81:6; 17:50).

The importance of bitumen quality is continuously stressed. Built-up roof system quality control can be

hindered because bitumen quality varies with the source, distilling process, refinement, and the introduction of chemical catalysts used to shorten processing (22:5-2, 6:1). There have been instances reported were bitumen has not met specifications (2:25). AFM 91-36 addresses this problem with bitumen quality.

> The current reference standards for roofing bitumens do not provide a meaningful standard of quality. As a result, they do not provide the desireable assurance that such bitumens will perform as intended. The wide variance in product quality is especially true of the asphalts [22:5-2].

An article on asphalt performance, however, took a somewhat different stand. It stated that if asphalt is properly heated, handled, and applied it will result in a built-up roof lasting 15 to 20 years (38:6).

Performance

Roofing performance was introduced in Chapter I to identify some of the factors and variables which impact the quality conformance and service life of a built-up roofing system. Performance topics will now be expanded with a concentration on what is required to extend the service life or prevent premature failures.

System Requirements. Service life is a common measure of the durability of a roofing system. It can be defined as the length of time the system adequately performs the desired function (31:2). Prior to the implementation of a roof management program and AFM 91-36, the United States Air Force Strategic Air Command expected an average service life of 12

years whether the roof was a replacement or new construction (73:29). William Cullen addressed a wider spectrum when he stated the following about performance:

> By far and large, the vast majority of all roofs in the United States are performing satisfactorily over their expected service life [18:334].

How are the expected service lives determined to compare with actual performance? Prediction can be drastically simplified when statements are made like the following:

> The roofing industry has traditionally assigned 5 years anticipated service life to each felt ply, that is, 20-year life for a four-ply membrane, 15-year life for a three-ply membrane, and so on [34:128].

> A well designed, four-ply built-up roof is very predictable and will last 20 years [71:90].

Canadian Building Digest 115 discusses the prediction of performance with a different viewpoint. The digest states predicting the service life of a built-up roof requires an understanding of material properties, knowledge of the interaction process between the system and environment, and consideration of environmental factors (63:4).

From these various statements on roofing performance, factors such as design, application process, workmanship, and material and environmental interactions can be identified as being significant. A discussion of the influence of design on performance, although important, except as presented previously in this report, is outside the scope of this study. The influence of the application process has also been introduced in an earlier chapter but will again be highlighted during the discussion on tolerances. Therefore,

effects of workmanship and material and environmental interaction will now be expanded.

Workmanship. Workmanship is a frequent topic when built-up roof performance is discussed. The importance of this factor on the service life of a roofing system has been expressed by several authors. For instance, a published book by M. C. Baker on built-up roofing discusses the subject with the following:

> Workmanship is extremely important in the application of roofing, and all mistakes or errors affect the life of a roofing system [7:278].

Several years previous to this statement, Baker wrote the following in a Canadian Building Digest:

> Construction of satisfactory built-up roofing is only possible if high standards are maintained in all phases of design and construction [6:4].

In a report by the Oak Ridge National Laboratory, workmanship is linked to performance with the following:

> To achieve good roof performance, one needs experienced roofing crews who understand how to cope with limitations imposed by weather [16:24].

Tolerances can be used as one way to control workmanship and therefore product quality. Quality workmanship has been shown to be essential in obtaining a built-up roofing system that performs satisfactorily. Does this, then, validate the statement that tolerances are an essential tool in constructing a roof which performs adequately through its expected service life?

Performance Attributes. Roofing systems are subjected to varying environmental conditions in any single

location or when considering roofs throughout the United States and the world. As previously stated, these conditions interacting with the roofing materials drastically impact performance. For instance, temperature and humidity interact with the various types of felts, decks, and insulation and degrees of exposure to influence membrane permeability (77:21).

To meet permeability and other requirements good construction practice is needed (13:166). Construction practice, as used in this context, can be loosely interpreted as referring to either workmanship or the attributes a roofing system requires to perform adequately. There appears to be two schools of thought regarding the use of roofing attributes or properties. One school believes the development of criteria will elevate the art of roofing to a science (79:2) and thus improve performance. The other school seems to believe current technology is sufficient. C. W. Griffin begins to express this view with the following:

> Improved performance depends less on purely technological progress than on a deeper understanding of the roof as a complex system of interacting components [34:18].

Since the research and use of performance attributes does attempt to understand the interaction of system components one may argue that only one school of thought exists. Another author strengthens the idea of two schools of thought, however, when adding that available technical information already exists making it possible to specify roof systems which will perform for their intended service lives (19:46-47).

Regardless of how many views exist as to the need for technological advances, built-up roofing research is pursuing the idea (77:3). In 1974 the National Bureau of Standards published Building Science Series 55, Preliminary Performance Criteria for Bituminous Membrane Roofing. This report identifies twenty attributes that effect membrane performance and explains laboratory tests for measuring the engineering properties that pertain to many of these attributes (79:1). Performance levels for nine of the attributes were recommended (79:10-11).

1. Tensile Strength
2. Thermal Expansion
3. Flexural Strength
4. Tensile Fatigue Strength
5. Flexural Fatigue Strength
6. Impact Resistance
7. Shear Strength
8. Wind Uplift Resistance
9. Fire Resistance

By 1981, Ed Rissmiller extended the NBS research and reduced the twenty properties essential to performance to twelve (18:335). The ARMA is attempting to put this research to use. The proposed ARMA design guide discusses several of these properties when addressing design considerations (3). In a 1982 article by Jack Williams on standards and tolerances, the requirement to utilize these properties, however, was described as not being established (83:33).

Built-Up Roofing Problems

Introduction. There are many reasons for built-up roofing failures. These reasons resemble the factors which impact the service life of roofs. For example poor design,

severe environmental conditions, lack of maintenance, poor workmanship, inadequate application procedures, poor quality control, materials of poor quality, and structural conditions of the building are potential reasons for failure of any roof (11:5; 15:171; 49:209; 14:1; 81:11-12). The situation is not dismal but is a concern for many. This concern is expressed by the following statement:

> While built-up roofing in general performs satisfactorily, premature failures cause unneeded complications and inordinate expenses for owners, roofing contractors, and material manufacturers [77:2; 81:94].

Before a roof fails to function adequately and permit water to infiltrate the building, several different roofing problems could develop. Problems typically discussed include blisters, slippage, splitting, migration, ridging, blow-off, flashing, alligatoring, delamination, surface erosion and surface oxidation (7:307). The NRCA publishes survey results, entitled Project Pinpoint, showing which of these problems occur most frequently. Survey results vary somewhat from year to year but blisters and splitting have been accounting for about 35 to 50 percent of all reported roofing deficiencies (60:43; 19:46; 20:37). Flashing problems are found to be the basis for approximately 3% of the deficiencies (19:46; 20:37). In Project Pinpoint, the NRCA also tries to let contractors, owners, and other interested parties know when these problems occur. For instance, a 1982 Project Pinpoint report revealed that 80 percent of all the problems identified in the survey were on roofs less than three years old (18:334).

Some of the most frequently occuring problems will be highlighted. A summary of potential causes of the various problems will be presented and suggested methods for prevention will be introduced. This information is provided with the intention of showing how and where tolerance setting, and adherence to these tolerances, can impact roofing problems and therefore failures.

Blisters. Blisters tend to be the most common type of roofing problem (84:91; 49:209-210). One source identified blisters as occuring twice as often as splits (34:279) but recent surveys do not support this (60:43; 19:46; 20:37). One reason for the concern over blisters, regardless of the number of times they occur, is the vulnerability to puncture, deterioration, and photochemical oxidation which results (34:280).

A blister is a swelling of the roof membrane (22:A1-1). These swells or blisters can develop in three areas of a roofing system; the surface, between plies, and between the insulation and membrane or the substrate and membrane (44:60; 81:210). Surface blisters are sometimes called pin, blueberry and pimpling blisters or bitumen bubbling (81:210). The remaining blisters are structural blisters called interply, interface or interphase blisters (80:32). Interply blisters being the most common (15:171).

Surface blisters are caused by moisture in the surface bitumen and can expose the top ply of felt (37:3; 7:307). Opinions concerning the creation of structural blisters,

however, vary. This is evidenced by an article on the subject entitled "Blistering Controversy Rages On." This and other literature on structural blister formation differ somewhat on the role of moisture and the size of the unbonded area required to initiate a blister. AFM 91-36 states that blisters are caused by voids, water and the heat of the sun (22:3-26). One source identifies water as the major requirement to create blisters (70:33) while another lists air as the principal element (7:319, 156-157). In a 1963 report by Frank Joy, of Pennsylvania University, research showed how water will increase pressures in the void (42:3). This fact is further supported by an article on interply adhesion and blistering stating a smaller void is required to create a blister if moisture is present (49:215). In general, though, the development of a blister depends on the presence of moisture, membrane temperature, type of felt and type of bitumen (25:369). Blisters can also grow by joining with adjacent voids or blisters (7:157; 34:291).

Prevention of interply blisters is accomplished by reducing voids while surface blisters can be prevented by removing moisture. Research has revealed that interply blisters rarely form if voids in the membrane are less than five percent of the total interply area; not an unreasonable requirement (25:370-371). More specific ways to prevent blisters follows (6:4; 22:5-6; 16:25; 25:370-371).

1. Ensure complete adhesion
2. Utilize proper application temperatures
3. Broom without delay
4. Use dry materials

5. Vent with porous or perforated felts
6. Eliminate stage construction
7. Accomplish laboratory testing
8. Ensure quality field control

The following opinion discusses testing and field control methods for void prevention.

> Visual inspection alone has not been found satisfactory, in the author's experience, because you can not "see" into the installed membrane to determine if excess voids are present [25:371].

The importance of perforated felts is shown by the following:

> The quality of perforations in organic roofing felt is at least as important in preventing interply voids and blisters as the bitumen technique used by a roofing crew [16:25].

The conclusion of a presentation by Dwight and Jennings, entitled Preventing Blistered Built-Up Roofs, summarizes the current situation with membrane blisters.

> Test data obtained over the past 20 years shows that blistering of built-up roof membranes need not be a problem. There is sufficient technical data now available to design a built-up roof membrane that will not split and that has sufficient waterproofing properties and durability characteristics [25:373].

Splitting. Whether blisters or splitting occurs more frequently is less important than how immediate the concern should be. For example, a blister may form but take a long period of time to cause the roof to fail; whereas, if a roof splits water can infiltrate immediately (84:91). There are several theories describing how splits occur. The majority of these theories being developed in the sixties. The Moisture Effects Theory, Shrinkage Theory, Lack of Restraint Theory, Faulty Application Theory, Material Changes Theory and Thermal Shock Theory (84:93-96) are the most prominent

that have received various levels of acceptance through the years.

Roofs are subject to varying degrees of stress originating for several reasons. The fluctuation of this stress may fatigue the roofing membrane and eventually lead to splitting (84:96). Stress can be generated from temperature variations, membrane shrinkage, moisture changes, structural movement, and roofing system component movement (41:4; 34:300). Although thermal stresses do not generally split membranes, like drying shrinkage, they do contribute to the problem (34:300-301, 319; 40:606). The major cause is movement of insulation, especially on large roofs where larger stresses can be generated (34:2-3). Splits will generally occur where resistance is limited such as at insulation joints, roof penetrations, and flashing joints (40:606; 7:324).

The materials, system temperature, and rate of strain influence the ability of the membrane to withstand the stresses (41:4). Membrane strength and elongation capabilities, two of the performance attributes previously mentioned, increase splitting resistance while bitumen hardening, from photo-oxidation, reduces the resistance (16:25; 41:2). Thermal stress can be limited through the use of expansion joints; proper direction of felt placement; proper component attachment; and proper interply bitumen application rates, since an overweight interply can increase the thermal coefficient of the membrane (15:172; 34:301).

Splitting from insulation movement can be reduced with the proper use of expansion joints and continuous attachment, but other steps such as taping insulation joints and limiting insulation gaps are beneficial (16:25; 13:172-173; 34:313). Prevention of splits, however, is not simply implementation of these various steps. For instance, if the deck is discontinuous, complete attachment of the system may aggravate the situation (15:171-172).

Ridging. According to Maxwell Baker, ridging is the wrinkling, buckling or formation of a narrow ripple in the roofing membrane generally occuring along insulation joints (7:322). There is no immediate danger with ridging but cracks may occur in the ridge allowing water to infiltrate.

The development of ridges is aggravated by the presence of moisture and requires temperatures high enough to cause movement in the felt layers (7:150; 42:14; 11:16, 18). Prevention of ridging is similar to recommendations made for preventing splitting. The risk of ridges developing can be reduced through the use of dry materials, firm attachment of the system, the staggering of joints when two layers of insulation is applied, and the installation of tight insulation joints (15:172). The NRCA quality control booklet shows how this last prevention method is not completely in the control of the roofer. Factors which influence how tight the insulation joint can be include the insulation manufacturing tolerances, dimensional stability, installation variables, and the nature of insulation boards (58:6).

Slippage. Slippage will occur when the resulting shear stress in the system is two high to be resisted by the various components (37:3). The actual slippage may take place between several layers of the built-up roofing system. Slippage can occur between adjacent felts, between the surfacing material and the membrane, between the insulation and the membrane, or between the insulation and the roof deck (81:221).

The severe shear stress, which causes the slippage, can be the result of a single contributing factor or a combination of several. These factors are inadequate attachment, a low bitumen softening point, heavy bitumen application rates, overweight aggregate or other surfacing material, a high roof surface temperature, and the inclusion of insulation in the system (15:172). The low softening point can be created during the bitumen heating process if overheating occurs (7:317). A heavy bitumen application reduces shear resistance (34:330). This is especially true between the base sheet and ply felts (15:172). Aggregate surfacing can drag membrane plies to the lower roof areas if the bitumen viscosity is low enough (15:172).

Steps which can be accomplished to reduce slippage risk involve staggering the end of the felt plies, using glass-fiber or perforated felts, limiting the bitumen and aggregate quantities, and controlling bitumen heating (34:30). C. W. Griffin recommends limiting application rates for asphalt from 15 to 20 pounds per 100 square feet and 20 to 25 pounds

per square feet for coal tar to reduce the risk of slippage (34:332). The importance of limiting the bitumen is reinforced by Maxwell Baker when adding that slippage may be more detrimental than deterioration due to insufficient quantities (7:294).

Flashing Defects. Although flashing problems do not occur as frequently as some other roofing problems, these defects account for most roof leaks (16:24; 22:5-7). Proper design and detailing of flashing construction is vital. John Watson lists 27 basic rules to insure proper flashings are constructed in his book Commercial Roofing Systems.

Alligatoring. Alligatoring is the result of a deterioration process which begins with photo-oxidation (7:308). The process continues with aging and hardening of the bitumen. Eventually random cracking occurs from contraction at low temperatures (34:334). These cracks may eventually admit water and penetrate the roofing system.

Roofing Problem Summary. There are many individuals and groups involved with the built-up roofing industry. Those contributing to the current situation include manufacturers, constructors, associations, inspectors, government agencies, researchers and owners (81:96). This involvement tends to create confusion and generate a product which is less than perfect (81:97). After construction, one must deal with moisture, structural movement, maintenance programs, environmental conditions, foot traffic, and atmospheric pollution (81:98). The outlook on built-up roofing, in the

author's opinion, is good. Roofing problems of the past have matured the built-up roof (28:129). Ken Schriber, a Dayton Ohio roofing contractor, commenting on improvement over the past ten years, stated the following:

> I'd say there has been a 100% improvement in built-up roofing. Seventy-five percent can be attributed to better products and 25% to better application [71:92].

Even with this type of improvement, however, problems and failures still occur on built-up roofs. A review of literature available concerning these problems has been presented. It has not been explicity pinpointed where tolerances may help prevent these problems. At present, it is up to each individual to determine this.

Tolerances

A quality policy is a broad guide to action geared to obtain specific goals (43:542, 547). In built-up roof construction, the goal, especially from the owners point of view, is to prevent premature failure and obtain a roof system which will function adequately for the expected period of time. Action resulting from a quality policy to reach this goal includes visual inspection and possibly roof sample testing. Visual inspection and sample analysis are parts of the Air Force quality assurance program. These actions attempt to ensure specified quality or quality standards are obtained. This use of quality standards in contract specifications being required in lieu of another appropriate metnod such as a performance specification (34:4).

A report by the U. S. Army Construction Engineering Research Laboratory has identified the following as the most persistent contract and quality standard violations [75:9].

1. Excessive bitumen temperature in the kettle
2. Bitumen temperature too low at application
3. Deviation from good working practice
4. Incorrect materials
5. Beginning contract without sufficient materials on site
6. Incorrect bitumen quantity
7. Staged construction

AFM 91-36 addresses all of the major violations to some degree. The Air Force requires the specification of tolerances on bitumen quantities and several other steps in the built-up roof construction process which are not identified as persistent violations. The controversy over the use of sampling was introduced in the background section of Chapter 1. The previous discussion of the two major positions on sample testing was not tolerance specific. More specific reasoning, however, has been expressed by various experts in the field and will now be presented. Following the presentation of these views, recommended tolerances and application rates for various parts of the construction process will be provided.

Viewpoints On Tolerance Use. Negative views on the use of tolerances begins with the use of quantitative measurements. One source explains the use of quantitative measurements in the quality assurance process of roofing applications is difficult because of the many terminations and other details which are part of a built-up system (16:25-26). Turning to the ability to meet tolerances,

Robert E. First stated that uniformity cannot be achieved with current methods (30:13) and materials. For instance, the question surfaces as to whether existing equipment is suitable to apply roofing materials to meet required standards (83:34). It may be easy to "blame" the roofer for nonuniform bituminous layers, improper application temperatures and inadequate brooming, but, what if bitumen quality is below that which is acceptable or if felt perforations are inadequate (15:171). When discussing the ability to meet tolerances, the variables involved in built-up roof construction must be considered. Bitumen application rates vary with job conditions, method of application, atmospheric temperature, available equipment, and roofer experience (58:7,9,11; 51:52). AFM 91-36 warns of deviations in the production process and states some deviation should be allowed (22:5-6).

Several comments exhibiting caution on the use of tolerances pertain to the ever important performance requirement. One manufacturer identifies good distribution to be more important to service-ability than weight (55:7). The NRCA quality control booklet agrees with this as evidenced by the following statement expressing caution:

> It can be misleading to judge the quality of a membrane with respect to performance and durability on the basis of the amount and uniformity of bitumen between individual plies. During state-of-the-art bituminous membrane construction, certain deviations from the specified interply bitumen rates are expected. A continuous, firmly bonding film of interply bitumen is the critical characteristic [58:7].

Robert First infers the establishment of tolerances is not a simple process and may not improve system performance with the following:

> There is no historical data to support the idea that a roof with uniform thickness and the same weight throughout will protect any better or last any longer than one with some deviations in thickness and weight [30:13].

C. W. Griffin also warns the use of tolerances may be a hinderance to obtain a quality product. The warning, however, deals with the use of tolerances that can not be met.

> Overly strict quality control practices, as evidenced by some now in use in the United States, which demand precision and accuracy greater than is possible at the present state of technology, may have a strongly negative impact on roof performance [34:46].

Positive views on the use and need for tolerances begins with a look at built-up roofing problems. Ed Schreiber shows the relation between variances and roof problems with the following:

> Most of the problems we've found with systems are not the product of the materials themselves - they're the product of the construction process. We've been involved in about one-quarter billion dollars worth of roofing failures, most of those were assignable to systems that were at variance with the quality of built-up roof specifications [48:7].

Many other comments indirectly promoting the use of tolerances deal with application rates and resulting problems if certain rates are not obtained. Proper application requires a sufficient amount of bitumen to obtain a continuous layer and provide sufficient strength but heavy layers are discouraged (80:1; 57:20; 51:52; 7:39).

> It has been shown by Cullen at the National Bureau of Standards in Washington that the amount of bitumen used affects the slipping potential on sloping roofs [7:39].

Robert First widens application rates to include surfacing embedment with the following:

> A good mopping of asphalt, producing a thin, continuous layer of bitumen between each ply of felt is essential. Evidence of a good flood coat of bitumen and embedding of a gravel layer are major checkpoints [30:13].

The NRCA Quality Control of Built-Up Roofing document, according to Wayne Mullis an NRCA past president, was spurred by the requirement of AFM 91-36 for a perfect roof [5:9]. William Cullen expressed support for the use of tolerances and summarized this view in 1984 by approving a goal of zero defects.

> It is time for the roofing industry to take a positive approach to seek a goal of zero defects in roofing performance rather than to address the old and new problems as they occur one by one and provide solutions that have little influence on the big picture of roofing performance [18:333].

Recommendations. Roof system application rates and material installation requirements are typically set by product manufacturers. Quality standards, however, are established by project designers or owners based on desires, goals, and recommendations from manufacturers and associations such as the NRCA and ARMA (45:47). Where do and should the contractors fit in to the process of setting built-up roofing tolerances? William Cullen has stated the following on the subject:

> The contractor segment of the industry has the expertise to define realistic variations to be expected under normal application practices [19:47].

AFM 91-36 identifies manufacturers as the most familar with the characteristics and capabilities (22:6-2). This impling that manufacturers should set tolerances.

Regardless of who should be ultimately responsible for establishing project tolerances, it is important to ensure tolerances are not too strict or too loose to reduce performance or lead to poor workmanship (26:24, 26). The critical factor in setting application standards, as Jack Williams states, is knowing what material quantities are necessary to obtain a roofing system which will perform adequately (83:33). Williams adds, however, that these quantities have not yet really been determined (83:33). A dilemma, at least for owners, therefore exists in specifying tolerances. Some of the main questions which need to be addressed include the following:

1. How much bitumen is required?
2. How much bitumen is too much?
3. What variances can be expected from roofers while constructing a roof with "conscientious" workmanship?
4. Is accepted equipment and methods adequate?
5. How much embedment is necessary?
6. How much aggregate is sufficient without contributing to problems?
7. Can voids be tolerated, and if so, to what degree?
8. What insulation joint size is acceptable?
9. What constitutes a headlap deficiency?
10. What is the cost of the specified tolerance?

Information already presented begins to answer these questions. To further assist with these questions recommended application rates and tolerances should be reviewed.

Application Rates. Common recommended application rates for various built-up roofing components are provided in tables 3.1 and 3.2. Owens-Corning qualifies application rates as uniform at a nominal rate. TAMKO provides recommendations while adding that the rates are for average conditions.

Manufacturers' recommend application rates are based on experience and research. Others, however, also conduct research to determine optimal rates. Research has typically been accomplished on interply rates and more often on asphalt than coal tar. This research has at times, arrived at somewhat different results. For instance:

> In 1972 Cramp, Cullen and Tyron recommended that the optimum application rate of asphalt in the fabrication of built-up membranes be within the range of 15 to 20 pounds per 100 square feet of area [80:12].

Testing by Boone, Skoda, and Cullen concluded the optimum interply bitumen quantity is somewhat less than currently called for rates of 20 to 25 pounds per 100 square feet (78:4-5). Watson indicates interply weights are based on custom with the following:

> Custom has dictated a mop coat weight of 20 to 25 pounds per square regardless of asphalt type, source, viscosity at the optimum mopping temperature, method of application, surface being mopped, or ambient temperature or wind-chill factor [81:106].

National Bureau of Standards Building Series 92 states that the interply application rate normally recommended by industry is 15 to 25 pounds per 100 square feet (80:13). In a discussion on manufacturer recommendations, Jack Williams indicates a lack of set standards with requirements from 20

to 28 pounds being recommended for interply bitumen rates (83:33). Regardless of what the recommendations are, Jim Koontz of Roof Engineering Inc., found actual interply application rates to be slightly above 25 pounds per 100 square feet (45:7).

Recommended Tolerances. Some of the tolerances currently recommended and specified are provided in tables 3.3 and 3.4. In an article by Jim Koontz, entitled "Bettering BUR Tolerances", a further listing is provided (45). For instance, the article shows tolerances of plus or minus 15 percent for interply and flood coat bitumen rates recommended by Celotex and GAF (45:6-7). Some manufacturers qualify recommendations. For instance, tolerances recommended by TAMKO concerning bitumen application rates are qualified as applying to average conditions and state excess variations can result at extreme temperatures (67:6).

Jack Williams presents some background on the introduction of tolerances for built-up roof interply weights. In 1961, one manufacturer recommended an interply bitumen rate of 20 pounds per square with a plus or minus 15 percent tolerance. The discussion states many manufacturers utilized the tolerance but not the application rate (83:33). The Manual of Built-Up Roof Systems recommends a check for a continuous uniform application with an average tolerance of plus or minus 15 percent (34:47). Specific research, related to Air Force tolerances stipulated in AFM 91-36, was conducted by the NRCA. The findings, based on a study to

Table 3.1

Asphalt Application Rates

	Flood Coat Weight (lbs/sq)	Interply Weight (lbs/sq)	Total Aggregate (lbs/sq)	Aggregate Embedment
OCF	not less than 60	nominal 25* nominal 20**		
Manville	approx 60	at 23	uniform 400-gravel 300-slag	embed
TAMKO	60	23	Approx 400-gravel 300-slag	embed
Genstar (Flinkote)	60	25	gravel or slag 400	embed
Canadian Building Digest 24	Approx 60	Approx 20		
Watson	60	20 to 25		embed
Joy	60	at least 25	400 gravel 300 slag	
AFM 91-36				min. 60%

* 3 inches or less slope
** more than 3 inch per foot slope

Table 3.2

Coal Tar Application Rates

	Flood Coat Weight (lbs/sq)	Interply Weight (lbs/sq)	Total Aggregate (lbs/sq)	Aggregate Embedment (%)
OCF	not less than 75	uniform nominal rate of 30		
Genstar (Flinkote)	75	25	Gravel or Slag-400	embed
Koppers	Avg. not less than 70	Avg. not less than 20	Not less than 400-gravel 300-slag	embed
Canadian Building Digest 24	Approx 60	Approx 20		
Watson	75 to 80	25 to 30	Approx 400-gravel 300-slag	embed
Joy	at least 75	at least 30	400 gravel 300 slag	
AFM 91-36				min. 60%

investigate the relationship between temperature and viscosity with application rates, stated that USAF interply tolerances were not likely to be met (19:47).

The NRCA quality control document introduces the inability to obtain uniformity given current state-of-the-art and process variables. The document adds that for bitumen application a variance of plus or minus 25 percent is "generally accepted" taken on a job average basis but corrective action based on this is impractical (58:12). One roofing consultant, however, has stated that this statement does not coincide with past recommendations from manufacturers (46). In a letter to the Air Force Engineering and Services Center, Richard Snyder discussed the position of the ARMA concerning the NRCA document.

> The ARMA Board of Directors recently met and reviewed the NRCA "Quality Control in the Application of Built-Up Roofing" document and voted unanimously to not endorse this particular version. There are a number of items in the NRCA document that are in direct conflict with manufacturer specifications [65].

These conflicts, though, were not expanded. One must wait for the ARMA to publish the design guide currently in review and compare the two.

Typically specified aggregate embedment values are 50, 60 and 100 percent. As listed in table 3.3 and 3.4, AFM 91-36 requires a 60 percent minimum (22:5-24). The NRCA quality control document recommends embedment of approximately onehalf of the applied aggregate (58:9). Very little information pertaining to optimum embedment quantities was

located. Some research, however, has been conducted concerning possible embedment. Testing, reported by Robert LaCosse, revealed reasonably attained values considerably higher than 50 percent with a test average of 71 percent (50:29,36). Embedment below 50 percent may be the result of tardy spreading of aggregate, excessive moisture, or dust on aggregate (34:149).

Like adhered aggregate few manufacturers recommend tolerances for headlap. NRCA and Air Force tolerances for headlap dimensions are provided in tables 3.3 and 3.4. Results of lap deficiencies have previously been examined. Surfice it to say that it is important to have the proper number of felt plies (30:13). With felt strength increases in recent years headlap deficiencies have decreased in importance.

Other aspects of built-up roof construction which may be controlled to some degree include bitumen temperature, voids, insulation gaps, end laps, and fastener spacing. AFM 91-36 does not address quality control of voids with the analysis method currently prescribed. A maximum void size or percentage of voids per interply area is therefore not specified by the manual. The NRCA quality control document, however, sets a maximum void size of two inches and states that overlapping and dry voids are not anticipated (58:15). Recall also research by Dwight and Jennings on blisters revealed infrequent blister formation were voids are less than five percent of total interply area with the average

Table 3.3

Asphalt Tolerances and Standards

	Flood Coat Weight	Interply Weight	Total Aggregate	Aggregate Embedment	Headlap
OCF		*min 23 lbs/sq max 45 lbs/sq	uniformly applied		
Manville	± 15%	± 15%			
TAMKO	not to exceed ± 15%	not to exceed ± 15%	Approx		
NRCA QC Document	average ± 25%			Approx 50%	-1 inch min. 1 inch
AFM 91-36	± 15%	± 15%	± 15%	minimum 60%	± 1/4 inch
ASTM	± 25%	± 20%	minimum 50% of specified	minimum 50%	

* less than 3 inch slope

Table 3.4

Coal Tar Tolerances and Standards

	Flood Coat Weight	Interply Weight	Total Aggregate	Aggregate Embedment	Headlap
OCF	min 25 lbs/sq max 40 lbs/sq				
Koppers	Average not less than	Average not less than	Not less than		
NRCA QC Document	average ± 25%			Approx 50%	-1 inch minimum 1 inch
AFM 91-36	± 15%	± 15%	± 15%	minimum 60%	± 1/4 inch
ASTM	± 25%	± 20%	minimum 50% of specified	minimum 50%	

worker, under average conditions, producing a system with less than three percent void area regardless of felt or bitumen (25:370).

Extensive research has been accomplished on bitumen application temperatures. The equiviscous temperature (EVT) is defined as the desireable bitumen temperature for proper fusion and wetting where the viscosity is between 100 and 150 centistokes (9:12; 24:122). Mop drag, improper bonding, improper bitumen weights, splitting, slippage, low tensile strengths, blisters, and nonuniform bitumen application can result if equiviscous temperatures are not followed (9:13). The equiviscous temperature is not an irrevocable figure to be used as a guide and should be adjusted to suit conditions in order to obtain the most workable viscosity (58:7).

AFM 91-36 requires a maximum insulation gap of 1/6 inch (22:5-24). The NRCA quality control booklet recommends 1/4 inch (58:6). Fastener spacing and endlap variances allowed by AFM 91-36 are established by general dimension variances (22:5-24). The recommended number and spacing of fasteners are both stipulated by the NRCA. For fastener spacing the specified value plus or minus 6 inches is recommended. For the number of fasteners the NRCA quality control booklet recommends a minimum equal to that specified minus 10 percent, or as required by local code or as required by factory mutual (58:5). Endlap variance recommendation by the NRCA document is minus two inches with a two inch minimum (58:8).

Summary. An overview of contract violations, application rates of various roofing components, and recommended tolerances has been provided. One must relate this information directly to roof problem causes and prevention methods and to built-up roofing components previously discussed in this chapter. It is also essential to consider these facts and views when reviewing the statistical analysis of roof sample test results conducted as part of this research.

Chapter Review and Summary

This descriptive study began with an introduction of built-up roofing components. An understanding of component roles and potential material quality problems is important in a discussion of tolerances. With this background information provided, answers to research questions 1, 2, 3, and 4 were given. With a discussion on performance topics and a review of built-up roofing problems, research question 1 was answered. This information enables one to identify where the use of tolerances may be beneficial. The remaining portions of this chapter answers questions 2, 3, and 4. Air Force tolerances, manufacturer recommendations, and other recommendations were provided. In addition comments on these various tolerances and recommendations were reviewed.

IV. Statistical Analysis Results and Findings

Chapter Overview

Chapter IV summarizes the results of the statistical and frequency analysis on Air Force built-up roof sample test reports. To answer research question 5, the chapter begins with some administrative facts concerning the test samples and presents some reasoning for the need for such an analysis. Following this information, analysis results are provided. Some general statements about the results conclude the chapter.

Analysis Introduction

Analysis Purpose. A tolerance defines the minimum and maximum values allowed for the resulting product (43:301). Knowing attainable tolerances provides a basis for setting tolerances. Statistics is one tool to determine what is attainable (43:35, 295). The following statement by Jack Williams identifies the need to know process capabilities more succinctly:

> What degree or level of preciseness of application is reasonably attainable in the field by trained, conscientious workmen using accepted methods and means of application [83:34]?

Key words in this statement include reasonably attainable; trained, conscientious workmen; and accepted methods and means. The problem is what does reasonably attainable mean? Also, does acceptable methods and means imply that new equipment will not be developed if determined necessary to meet tolerances which will increase performance?

Given state-of-the-art construction techniques and materials, it is essential to specify practical tolerances. Practical being available, useable, or valuable in practice (82:1937). Taking one step to ensure specified tolerances are practical, this analysis provides an indication of what variances may be expected based on past variances. This type of data is typically used to identify what is called a statistical tolerance limit. A statistical tolerance limit indicates the amount of variation that the process exhibits (43:301).

During the research stage of this investigation, it was discovered that the American Society for Testing and Materials (ASTM) may be pursuing the same information. ASTM Task Group D08.20.15 is developing a document on built-up roofing tolerances (1). A brief summary of the document contents follows.

> The ASTM document is attempting to assign precise numeric ranges to various weights and dimensions of roofing materials as determined by laboratory analysis of test cuts taken from completed roofs. Ranges presently under consideration are derived from statistical analysis of the data bases from several testing laboratories [54].

Analysis Facts. The roof sample test data was obtained from three separate testing laboratories - Roof Engineering, Inc., Hobbs, New Mexico; Chicago Testing Laboratory, Inc., Northbrook, Illinois; and INSPEC, Inc., Minneapolis, Minnesota. Information extracted from these sample results include required and tested bitumen rates, required and tested aggregate quantities, required and tested aggregate embedment, and required and tested headlap for the years 1982

to 1985. Asphalt and coal tar sample test results were investigated. Although the quality control process of AFM 91-36 requires insulation joints to be a maximum of one-sixteenth of an inch and stipulates allowable fastener spacing, this information was not available on the sample test reports. Also, AFM 91-36 requires monitoring and control of bitumen temperatures but this information was not obtained. The number of samples available for analysis of aggregate quantity and aggregate embedment were limited because values for required quantities were not available from Roof Engineering, Inc. as provided from the firms printed computerized data base. Complete data listings are provided in the appendices.

Analysis Findings and Results

Recall research question 5 asks what variances have been obtained in past Air Force built-up roofing construction projects. Tables 4.1 through 4.11 (pages 62-72) answer this question. These tables summarize and provide pertinent information regarding these variances. Tables 4.1 through 4.6 pertain to projects requiring the use of hot asphalt. The remaining tables contain coal tar analysis results. Appendix B contains complete analysis results for asphalt projects while complete coal tar results are located in Appendix C.

Table 4.1, Summary - Asphalt Flood Coat, includes a special breakout of variances concerning double pours. The individual years from 1982 to 1985 include double pour sample

analysis results. Where the data base is combined to provide comprehensive results for 1982 through 1985, the first column includes double pour samples. The second column, under this heading, does not include double pours. The third column are the results of double pour samples alone.

AFM 91-36 requires flood coat bitumen application quantities to be as specified plus or minus 15 percent. Approximately 39 percent of the asphalt samples met this requirement, while about 42 percent met it for coal tar projects. The greatest adherence to specified rates of asphalt occured in 1984 with 44.0 percent within the 15 percent tolerance. For coal tar, 54.8 percent of the 1983 samples were within the allowable variance.

Interply variances, as one might expect, were smaller in magnitude. The mean asphalt interply variance was determined to be slightly less than 18 percent. A mean variance of approximately 22 percent occured with available coal tar roofing samples. Mean variances were determined by taking the mean of the absolute variances. Almost 54 percent of the asphalt test reports meet the 15 percent allowable tolerance requirement of AFM 91-36 for interply weights. A somewhat lesser quantity, 46.6 percent, of the coal tar samples met the same requirement.

Tables 4.3 and 4.9 present headlap analysis results. These tables include mean headlaps occuring in the tested projects. All projects sampled required a two inch headlap. A mean headlap of 2.1 inches was determined for both asphalt

and coal tar projects tested. AFM 91-36 requires compliance of the two inch headlap plus or minus 0.25 inches. Of the 1686 asphalt samples included in the analysis, 41.1 percent were within a quarter of an inch of the specified two inch headlap. With the coal tar samples only 33.8 percent met the same criteria.

AFM 91-36 requires total aggregate quantities to be within 15 percent of the amount specified. For the period from 1982 to 1985, a 44 percent compliance rate was determined with hot asphalt. For coal tar, only about 26 percent complied with AFM 91-36. Of those projects sampled requiring 400 pounds per 100 square feet, a mean application rate for asphalt was found to be 447.7. The mean for coal tar samples was 489.5 pounds per 100 square feet.

Aggregate embedment was examined primarily for those samples specifying a 60 percent minimum although table 4.6 provides results based on a 100 percent embedment requirement. Mean embedment of available samples tested from 1982 to 1985 were 71.1 percent for asphalt and 67.1 percent for coal tar. Almost 67 percent of the asphalt samples met the 60 percent minimum embedment. For coal tar, 59.4 percent of the samples met the requirement.

Table 4.1

Summary - Asphalt Flood Coat Results

	1982	1983	1984	1985	1982-1985 With	Double No	Only
Mean Variance (%)	39.6	29.0	31.1	32.9	31.7	31.7	31.9
Standard Deviation (%)	39.4	24.8	48.3	41.3	40.9	42.8	26.4
Number Samples	61	336	507	628	1532	1315	217
Percent Within 15% Variance	29.5	35.4	44.0	37.6	38.9	40.8	27.6
Percent Within 20% Variance	36.1	45.8	52.9	48.9	49.0	50.4	40.6
Percent Within 25% Variance	44.3	52.1	62.5	56.8	57.2	58.4	49.8

Table 4.2

Summary - Asphalt Interply Results

	1982	1983	1984	1985	1982-1985
Mean Variance (%)	25.4	16.2	17.7	17.5	17.6
Standard Deviation (%)	28.9	14.1	15.5	14.0	15.5
Number Samples	68	383	575	663	1689
Percent Within 15% Variance	42.6	57.4	54.8	52.3	53.9
Percent Within 20% Variance	54.4	67.9	66.1	65.8	65.9
Percent Within 25% Variance	63.2	75.2	76.0	77.7	76.0

Table 4.3

Summary - Headlap Results
Asphalt Bitumen

	1982	1983	1984	1985	1982-1985
Mean Headlap (inches)	2.31	2.10	2.07	2.10	2.10
Standard Deviation (inches)	1.25	0.99	0.94	0.82	0.92
Mean Difference (inches)	0.72	0.64	0.59	0.53	0.59
Standard Deviation of Difference (inches)	1.02	0.76	0.74	0.63	0.72
Number Samples	64	385	575	662	1686
Percent Within 0.25 inch Difference	34.4	35.1	40.7	45.6	41.1
Percent Within 0.50 inch Difference	59.4	65.2	67.0	69.3	67.2
Percent Within 0.75 inch Difference	73.4	74.8	74.1	77.5	75.6

Table 4.4

Summary - Total Aggregate Quantity
Asphalt Bitumen

	1982	1983	1984	1985	1982-1985	1982-1985 lb/sq 400	1982-1985 lb/sq 300
Sample Mean (Pounds Per Square)	N/A	N/A	N/A	N/A	N/A	447.7	334.8
Sample Standard Deviation (Pounds Per Square)	N/A	N/A	N/A	N/A	N/A	138.3	70.7
Mean Variance (%)	25.7	21.1	29.8	26.2	25.6	25.8	19.9
Standard Deviation of Variance (%)	16.7	21.6	31.3	22.8	23.7	26.0	16.8
Number Samples	57	132	93	308	590	426	23
Percent Within 15% Variance	31.6	53.0	34.4	40.3	41.4	44.1	56.5
Percent Within 20% Variance	42.1	62.1	43.0	49.0	50.3	54.0	60.9
Percent Within 25% Variance	49.1	67.4	51.6	57.5	58.0	60.3	65.2

Table 4.5

60% Required Embedment
Asphalt Bitumen 1982 - 1985

Mean Embedment	71.1%	Standard Deviation from Requirement	22.4%
Minimum	6.9%	Maximum	100.0%

Percent Embedded Aggregate	Number Samples	Percent	Cummulative Percent
100	67	16.2	16.2
min 90	47	11.4	27.6
min 80	48	11.6	39.2
min 70	55	13.3	52.5
min 60	59	14.3	66.8
min 50	52	12.6	79.4
min 40	49	11.9	91.3
min 30	29	7.0	98.3
min 20	1	0.2	98.5
min 10	3	0.7	99.3
under 10	3	0.7	100.0
	413	100.0	

Table 4.6

100% Required Embedment
Asphalt Bitumen 1982 - 1985

Mean Embedment	81.7%	Standard Deviation from Requirement	16.6%
Minimum	31.5%	Maximum	100.0%

Percent Embedded Aggregate	Number Samples	Percent	Cummulative Percent
100	27	17.4	17.4
min 90	34	21.9	39.4
min 80	33	21.3	60.6
min 70	24	15.5	76.1
min 60	18	11.6	87.7
min 50	10	6.5	94.2
min 40	6	3.9	98.1
min 30	3	1.9	100.0
min 20	0	0	100.0
min 10	0	0	100.0
under 10	0	0	100.0
	155	100.0	

Table 4.7

Summary - Coal Tar Top Pour Results

	1982	1983	1984	1985	1982-1985
Mean Variance (%)	38.2	29.6	36.3	28.8	33.7
Standard Deviation (%)	29.3	50.6	51.6	27.9	46.9
Number Samples	30	124	368	127	649
Percent Within 15% Variance	33.3	54.8	40.2	34.6	41.6
Percent Within 20% Variance	33.3	65.3	51.1	44.1	51.6
Percent Within 25% Variance	33.3	70.2	60.1	55.1	59.8

Table 4.8

Summary - Coal Tar Interply Results

	1982	1983	1984	1985	1982-1985
Mean Variance (%)	21.1	31.1	17.5	24.9	21.8
Standard Deviation (%)	20.6	25.2	12.4	20.1	18.4
Number Samples	39	125	369	141	674
Percent Within 15% Variance	53.8	38.4	51.2	39.7	46.6
Percent Within 20% Variance	59.0	44.0	61.5	50.4	55.8
Percent Within 25% Variance	69.2	48.8	75.1	66.0	66.2

Table 4.9

Summary - Headlap Results
Coal Tar Bitumen

	1982	1983	1984	1985	1982-1985
Mean Headlap (inches)	2.5	2.0	2.0	2.2	2.1
Standard Deviation (inches)	1.3	0.9	0.8	1.2	1.0
Mean Difference (inches)	1.0	0.7	0.5	0.8	0.6
Standard Deviation of Difference (inches)	0.9	0.6	0.6	1.0	0.7
Number Samples	39	123	362	138	662
Percent Within 0.25 inch Difference	20.5	30.1	37.6	31.2	33.8
Percent Within 0.50 inch Difference	43.6	52.8	70.2	61.6	63.6
Percent Within 0.75 inch Difference	48.7	65.9	78.7	67.4	72.2

Table 4.10

Summary - Total Aggregate Quantity
Coal Tar Bitumen

	1982	1983	1984	1985	1982-1985	1982-1985 400 lb/sq
Sample Mean (Pounds Per Square)	N/A	N/A	N/A	N/A	N/A	489.5
Sample Standard Deviation (Pounds Per Square)	N/A	N/A	N/A	N/A	N/A	152.1
Mean Variance (%)	22.3	39.0	34.9	39.8	34.6	34.2
Standard Deviation of Variance (%)	16.4	36.8	27.1	24.8	27.5	27.8
Number Samples	25	28	107	31	191	160
Percent Within 15% Variance	32.0	28.6	29.0	9.7	26.2	26.9
Percent Within 20% Variance	56.0	39.3	37.4	25.8	38.2	38.8
Percent Within 25% Variance	60.0	53.6	44.9	38.7	47.1	48.1

Table 4.11

60% Required Embedment - Coal Tar Bitumen
1982 - 1985

Mean Embedment	67.1%	Standard Deviation from Requirement	24.1%
Minimum	14.0%	Maximum	100.0%

Percent Embedded Aggregate	Number Samples	Percent	Cummulative Percent
100	29	17.1	17.1
min 90	15	8.8	25.9
min 80	15	8.8	34.7
min 70	20	11.8	46.5
min 60	22	12.9	59.4
min 50	21	12.4	71.8
min 40	24	14.1	85.9
min 30	14	8.2	94.1
min 20	8	4.7	98.8
min 10	2	1.2	100.0
under 10	0	0.0	100.0
	170	100.0	

General Discussion of Analysis

Some extreme variances were identified during the statistical analysis. For example, one sample varied from the specified asphalt flood coat quantity by 479 percent. An interply quantity, also for asphalt, had a variance of 165 percent. One headlap measurement was 6.7 inches from the required quantity. The largest aggregate quantity variance, of all the samples, was 190 percent. One way to approach these extreme values is simply to exclude such values from consideration (43:40). This reasoning has both positive and negative support. If any values are dropped, one must assume these are unrepresentative due to some extraneous factor. Built-up roofing construction is impacted by many factors which are not extraneous. For this reason all values were considered. Valid reasoning for exclusion of these outliers was not provided with sample test results.

Ladislav Jerga, from Roof Systems Laboratory of Southfield Michigan, has conducted similar statistical analysis on built-up roofing variances. Some of the research conducted by Ladislav Jerga has been made available (39). It is included herein for comparison purposes. A partial summary of these independent results, based on Air Force roof sample results, between 1980 and 1983, are provided in tables 4.12 through 4.15.

Table 4.12

Independent Results
Coal Tar Surface Bitumen

Percent Variance	Percent Within Variance
15	17
25	31

Total Number of Samples: 190

Table 4.13

Independent Results - Interply Bitumen

Percent Variance	Cummulative Samples Within Variance	Percent of Total Samples
± 5	96	18.8
± 10	176	34.4
± 15	221	43.2
± 20	319	62.4
± 25	360	70.5
± 30	393	76.9
over ± 30	511	100.0

Table 4.14

Independent Results - Total Aggregate Weight
400 Pounds Per Square Required

Year	Mean	Standard Deviation	Percent Within 15% Variance
1981	402	106	65
1982	367	123	63
1983	464	135	48

Table 4.15

Independent Results - Headlap Width
2-inch Requirement

Year	Mean	Standard Deviation	Percent Within 0.25 Inches
1981	2.25	0.87	35
1982	2.05	0.82	37
1983	2.08	0.71	53

V. Conclusions and Recommendations

Chapter Overview

The descriptive study and statistical analysis, presented in previous chapters, have considerable value. Each research question developed in Chapter I has been answered. A brief summary of the answers to these questions will help conclude this research. Following that, the significance of this investigation will be discussed. The final section of this chapter provides recommendations on the use of this research and for further research.

Conclusions

Descriptive Study. The descriptive study of Chapter III provides a general review of published knowledge on built-up roofing topics dealing directly or indirectly with tolerances. The information in this review answers research questions 1 through 4. These four questions are as follows:

1. For which aspects of built-up roofing applications does existing research and technology indicate that tolerances should be specified?

2. On what aspects of built-up roofing systems does the Air Force specify tolerances?

3. What built-up roofing tolerances are specified by Air Force built-up roof construction projects?

4. What built-up roofing tolerances are recommended by others?

An understanding of the major built-up roofing system components together with a review of built-up roofing problems and system requirements for adequate performance,

assists one in deciding where tolerances may be of benefit. Predominant areas of concern in a built-up roofing system, where evidence shows that tolerances may benefit include: voids, insulation gaps, bitumen quantities, aggregate quantities, aggregate embedment, fastener spacing, headlap, and endlap. AFM 91-36 sets standards in all these areas except for voids. Voids, however, are becoming less significant with increased use of glass felts. Manufacturers generally make recommendations for allowable variances concerning bitumen quantities but seldom for these other areas. Air Force tolerances and recommendations from other sources, are provided in tables 3.3 and 3.4 of Chapter III.

Statistical Analysis. Research question 5 asks what variances have Air Force contracted roofing contractors obtained in the past. The statistical analysis of this investigation provides an answer. The analysis involves bitumen weights, headlap measurements, total aggregate quantities, and aggregate embedment. The analysis includes both asphalt and coal tar sample test results.

No clearly identified trends were recognized from a review of yearly results. Of the several areas of built-up roof construction analyzed, aggregate embedment best met Air Force requirements. Adherence to bitumen quantity rates was much greater for interply weights than for flood coat as might be expected. Neither, though, had a large percentage meeting the plus or minus 15 percent allowable variance of AFM 91-36. Approximately 40 percent of the samples met the

flood coat requirement, while 54 percent of the asphalt and 47 percent of the coal tar samples were within the interply bitumen quantity allowable variance. Total aggregate quantity and headlap requirements were both found to be within Air Force standards approximately 41 percent of the time for asphalt projects and closer to 30 percent when coal tar was specified. A much larger percentage of the tested headlaps, more than 63 percent, were within 0.5 inches of the 2.0 inch specified amount.

Significance. There is variability in materials, the process and worker capabilities. Tolerances are specified to indicate allowable limits of variability. Selection of tolerances, in theory, should be based on a balance of required precision and the cost factors involved in obtaining that precision (43:178). Setting tolerances for built-up roofing construction can not be accomplished in the same manner as many manufactured products. The "required" level of precision to generate "optimum" performance has yet to be completely established. Tolerances, therefore, are specified to ensure quality conformance, with performance a secondary, but important, goal.

Selection of realistic tolerances is difficult due to the variables involved in the process. Loose tolerance may produce an unsatisfactory product while tolerances that are too tight may make compliance impossible. Some of the consequences of improperly specified tolerances include the identification of many deficiencies, a great deal of rework,

construction delays, and friction between the owner and contractor (43:266).

> Only when process capability and product tolerances are compatible with each other and with the functional performance requirements of the finished product, can inspection and quality control perform a useful role [27:105].

Process capability is defined as the least variability of quality that is inherent in the process and which the process is capable of maintaining (27:108; 43:272). Reviewing the analysis results, it is apparent the process has a large amount of variability. The standard deviations determined during the course of the statistical analysis exhibit this variability. In a text on statistical quality control, Jerome Braverman identifies process capability as the mean value plus/minus three standard deviations (10:100-101). This range has also been identified as the "natural tolerance" of a process (69:682). These values are provided in table 5.1. To directly apply these statistical findings the process must be in control (10:101; 43:294). For a process to be in control the process must be free of assignable causes of large amounts of variation (10:117-118; 43:294). This is not the current situation with built-up roofing construction. Inferences, therefore, must be made regarding tolerances for the present and decisions made about future process capability.

> If management decides that the existing capability limits are not satisfactory, they are then faced with the problem of deciding whether or not the process can and should be improved [10:106].

A statistical tolerance limit can be developed from the conducted analysis. A statistical tolerance limit differs from the process capability or natural tolerance. A statistical tolerance limit contains a specified proportion of the total population with a given confidence level (43:301). The problem in determining the statistical tolerance limit is the selection of this confidence level and proportion of sample population to be contained. An example of tolerances for bitumen quantity, headlap, and total aggregate is provided in table 5.1 using this method. To determine these values a confidence level of 90 percent and a proportion of 75 percent of the samples was used. For asphalt samples, a sample size of 1000 was used obtaining a factor of 1.19. This factor was multiplied with the standard deviation to determine the statistical tolerance. For coal tar, a sample size of 500 resulted in a factor of 1.20.

The values presented in table 5.1 show how difficult it is to apply statistics in the setting of tolerances. To ensure quality conformance tolerances are recommended at levels lower than can be justified by currently completed analyses. The question for management then remains - What percentage of the samples must be within the specified tolerance to justify continued use of the tolerance? The results, however, definitely generate the requirement to vary the allowable variance depending on the component.

Table 5.1

Tolerance Summary

		Flood Coat	Interply	Headlap	Total Aggregate
	Air Force Tolerance	15%	15%	0.25 inches	15%
Asphalt	Mean Variance	31.7%	17.6%	0.59 inches	25.6%
	Natural Tolerance	122.7%	46.5%	2.16 inches	71.1%
	*Statistical Tolerance	48.7%	18.4%	0.86 inches	28.2%
	**Maximum Recommended Tolerance	25%	20%	1.0 inches	-
Coal Tar	Mean Variance	33.7%	21.8%	0.60 inches	34.2%
	Natural Tolerance	140.7%	55.2%	2.10 inches	83.4%
	*Statistical Tolerance	56.3%	22.1%	0.84 inches	33.4%
	**Maximum Recommended Tolerance	25%	20%	-	-

* J.M. Juran. Quality Planning and Analysis, pg 299, 613.

** Based On Descriptive Study Findings

Recommendations

The market quality, or quality of built-up roofing acceptable by all (43:446), has yet to be determined. To establish this quality level, continued research is essential. Research must continue in the areas of performance requirements and statistical control.

Experimentation on system components will undoubtedly continue. Values must be established giving a range of application quantities which will provide optimum performance while limiting the chance of roofing problems. Once this information is determined it must be made available to all. To accomplish this, field testing must be completed similar to response surface methodology. This methodology is described as a technique in which important characteristics are varied and measurements are made to evaluate performance (43:297). A slight variation to this would be to investigate the relationship, if any, between attained variances and maintenance requirements for the roof as time progresses.

The use of statistical quality control in built-up roofing is new compared with the length of time built-up roofs have been applied. The use of statistics, in the author's opinion, will and should continue. A great deal more statistical analysis has been accomplished than has been released to the public and organizations such as the Air Force. This is being done for reasons of liability or propriety. The Air Force, therefore is forced to conduct such investigations. Further analysis would be beneficial to

assist in selecting tolerances. Continued work on process capability is also essential. Other research which would determine workmanship consistency of individual contractors, versus contractors as a whole, would compliment this investigation. In addition, variances based on a job average basis, by geographical region and by construction season, is desired. If for no other reason the Air Force may see further statistical analysis as beneficial for it can show how well contract requirements are met. This would in turn indicate the effectiveness of the quality assurance program.

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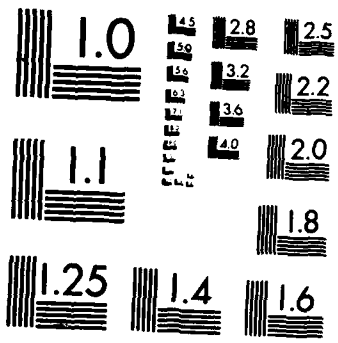

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B. Asphalt Analysis Results

Asphalt Flood Coat
1982

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	7	7	11.5
± 10	5	12	19.7
± 15	6	18	29.5
± 20	4	22	36.1
± 25	5	27	44.3
± 30	4	31	50.8
± 35	3	34	55.7
± 40	1	35	57.4
over ± 40	26	61	100.0
	61		

Mean Variance: 39.646% Standard Deviation: 39.436%

Minimum Variance: 1.17% Maximum Variance: 228.50%

Average Under Specified: 28.874% Average Over Specified: 46.248%

Asphalt Flood Coat
1983

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	40	40	11.9
± 10	43	83	24.7
± 15	36	119	35.4
± 20	35	154	45.8
± 25	21	175	52.1
± 30	26	201	59.8
± 35	30	231	68.8
± 40	15	246	73.2
over ± 40	90	336	100.0
	336		

Mean Variance: 29.045%　　Standard Deviation: 24.759%

Minimum Variance: 0.00%　　Maximum Variance: 170.82%

Average Under Specified: 26.349%　　Average Over Specified: 33.159%

Asphalt Flood Coat
1984

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	69	69	13.6
± 10	70	139	27.4
± 15	84	223	44.0
± 20	45	268	52.9
± 25	49	317	62.5
± 30	35	352	69.4
± 35	29	381	75.1
± 40	27	408	80.5
over ± 40	99	507	100.0
	507		

Mean Variance:	31.094%	Standard Deviation:	48.318%
Minimum Variance:	0.00%	Maximum Variance:	479.00%
Average Under Specified:	15.920%	Average Over Specified:	44.519%

Asphalt Flood Coat
1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	89	89	14.2
± 10	73	162	25.8
± 15	74	236	37.6
± 20	71	307	48.9
± 25	50	357	56.8
± 30	34	391	62.3
± 35	41	432	68.8
± 40	34	466	74.2
over ± 40	162	628	100.0
	628		

Mean Variance:	32.911%	Standard Deviation:	41.291%
Minimum Variance:	0.00%	Maximum Variance:	346.67%
Average Under Specified:	23.541%	Average Over Specified:	41.930%

Asphalt Flood Coat
1982-1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	205	205	13.4
± 10	191	396	25.8
± 15	200	596	38.9
± 20	155	751	49.0
± 25	125	876	57.2
± 30	99	975	63.6
± 35	103	1078	70.4
± 40	77	1155	75.4
over ± 40	377	1532	100.0
	1532		

Mean Variance:	31.730%	Standard Deviation:	40.862%
Minimum Variance:	0.00%	Maximum Variance:	479.00%
Average Under Specified:	21.927%	Average Over Specified:	41.558%

Asphalt Flood Coat
(Double Flood Coats Excluded)
1982-1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	180	180	13.7
± 10	169	349	26.5
± 15	187	536	40.8
± 20	127	663	50.4
± 25	105	768	58.4
± 30	80	848	64.5
± 35	91	939	71.4
± 40	66	1005	76.4
over ± 40	310	1315	100.0
	1315		

Mean Variance:	31.701%	Standard Deviation:	42.788%
Minimum Variance:	0.00%	Maximum Variance:	479.00%
Average Under Specified:	20.909%	Average Over Specified:	41.996%

Asphalt Flood Coat
Double Pours Only
1982-1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	25	25	11.5
± 10	22	47	21.7
± 15	13	60	27.6
± 20	28	88	40.6
± 25	20	108	49.8
± 30	19	127	58.5
± 35	12	139	64.1
± 40	11	150	69.1
over ± 40	67	217	100.0
	217		

Mean Variance: 31.905%

Standard Deviation: 26.408%

Minimum Variance: 0.00%

Maximum Variance: 170.82%

Average Under Specified: 27.158%

Average Over Specified: 38.356%

Asphalt Interply
1982

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	13	13	19.1
± 10	11	24	35.3
± 15	5	29	42.6
± 20	8	37	54.4
± 25	6	43	63.2
± 30	7	50	73.5
± 35	4	54	79.4
± 40	5	59	86.8
over ± 40	9	68	100.0
	68		

Mean Variance:	25.429%	Standard Deviation:	28.928%
Minimum Variance:	1.20%	Maximum Variance:	165.0%
Average Under Specified:	12.837%	Average Over Specified:	34.792%

Asphalt Interply
1983

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	93	93	24.3
± 10	70	163	42.6
± 15	57	220	57.4
± 20	40	260	67.9
± 25	28	288	75.2
± 30	33	321	83.8
± 35	28	349	91.1
± 40	10	359	93.7
over ± 40	24	383	100.0
	383		

Sample Mean:	16.230%	Standard Deviation:	14.108%
Minimum Variance:	0.00%	Maximum Variance:	79.96%
Average Under Specified:	12.140%	Average Over Specified:	19.564%

Asphalt Interply
1984

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	105	105	18.3
± 10	117	222	38.6
± 15	93	315	54.8
± 20	65	380	66.1
± 25	57	437	76.0
± 30	45	482	83.8
± 35	26	508	88.3
± 40	23	531	92.3
over ± 40	44	575	100.0
	575		

Sample Mean:	17.666%	Standard Deviation:	15.455%
Minimum Variance:	0.00%	Maximum Variance:	87.20%
Average Under Specified:	11.547%	Average Over Specified:	21.988%

Asphalt Interply
1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	99	99	14.9
± 10	132	231	34.8
± 15	116	347	52.3
± 20	89	436	65.8
± 25	79	515	77.7
± 30	44	559	84.3
± 35	42	601	90.6
± 40	27	628	94.7
over ± 40	35	663	100.0
	663		

Sample Mean: 17.481%

Standard Deviation: 14.001%

Minimum Variance: 0.00%

Maximum Variance: 152.17%

Average Under Specified: 15.803%

Average Over Specified: 19.427%

Asphalt Interply
1982-1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	310	310	18.4
± 10	330	640	37.9
± 15	271	911	53.9
± 20	202	1113	65.9
± 25	170	1283	76.0
± 30	129	1412	83.6
± 35	100	1512	89.5
± 40	65	1577	93.4
over ± 40	112	1689	100.0
	1689		

Sample Mean:	17.580%	Standard Deviation:	15.468%
Minimum Variance:	0.00%	Maximum Variance:	165.00%
Average Under Specified:	13.628%	Average Over Specified:	21.095%

1982 Headlap
(Asphalt Bitumen)

Difference From Specified (inch)	Number Samples (Frequency)	Cummulative Number Samples	Cummulative Percent Within Difference
under ± 0.25	22	22	34.4
± 0.50	16	38	59.4
± 0.75	9	47	73.4
± 1.00	4	51	79.7
± 1.25	1	52	81.3
over ± 1.25	12	64	100.0
	64		

Mean Headlap:	2.309 inches	Standard Deviation:	1.245 inches
Mean Difference:	0.772 inch	Standard Deviation: of Difference	1.020 inches
Minimum Variance:	0.00 inch	Maximum Variance:	5.80 inches
Average Under Specified:	0.477 inch	Average Over Specified:	1.048 inches

1983 Headlap
(Asphalt Bitumen)

Difference From Specified (inch)	Number Samples (Frequency)	Cummulative Number Samples	Cummulative Percent Within Difference
under ± 0.25	135	135	35.1
± 0.50	116	251	65.2
± 0.75	37	288	74.8
± 1.00	28	316	82.1
± 1.25	12	328	85.2
over ± 1.25	57	385	100.0
	385		

Mean Headlap: 2.095 inches

Standard Deviation: 0.989 inch

Mean Difference: 0.640 inch

Standard Deviation: of Difference 0.759 inch

Minimum Variance: 0.00 inch

Maximum Variance: 4.60 inches

Average Under Specified: 0.507 inch

Average Over Specified: 0.795 inch

1984 Headlap
(Asphalt Bitumen)

Difference From Specified (inch)	Number Samples (Frequency)	Cummulative Number Samples	Cummulative Percent Within Difference
under ± 0.25	234	234	40.7
± 0.50	151	385	67.0
± 0.75	41	426	74.1
± 1.00	43	469	81.6
± 1.25	22	491	85.4
over ± 1.25	84	575	100.0
	575		

Mean Headlap: 2.067 inches

Standard Deviation: 0.944 inch

Mean Difference: 0.593 inch

Standard Deviation: of Difference 0.737 inch

Minimum Variance: 0.00 inch

Maximum Variance: 6.70 inches

Average Under Specified: 0.511 inch

Average Over Specified: 0.680 inch

1985 Headlap
(Asphalt Bitumen)

Difference From Specified (inch)	Number Samples (Frequency)	Cummulative Number Samples	Cummulative Percent Within Difference
under ± 0.25	302	302	45.6
± 0.50	157	459	69.3
± 0.75	54	513	77.5
± 1.00	52	565	85.3
± 1.25	12	577	87.2
over ± 1.25	85	662	100.0
	662		

Mean Headlap: 2.099 inches

Standard Deviation: 0.818 inch

Mean Difference: 0.529 inch

Standard Deviation: of Difference 0.631 inch

Minimum Variance: 0.00 inch

Maximum Variance: 4.50 inches

Average Under Specified: 0.412 inch

Average Over Specified: 0.656 inch

1982-1985
Headlap
(Asphalt Bitumen)

Difference From Specified (inch)	Number Samples (Frequency)	Cummulative Number Samples	Cummulative Percent Within Difference
under ± 0.25	693	693	41.1
± 0.50	440	1133	67.2
± 0.75	141	1274	75.6
± 1.00	127	1401	83.1
± 1.25	47	1448	85.9
over ± 1.25	238	1686	100.0
	1686		

Mean Headlap: 2.095 inches

Standard Deviation: 0.921 inch

Mean Difference: 0.585 inch

Standard Deviation of Difference: 0.717 inch

Minimum Variance: 0.00 inch

Maximum Variance: 6.70 inches

Average Under Specified: 0.470 inch

Average Over Specified: 0.711 inch

1982
Total Aggregate Quantity
(Asphalt Bitumen)

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	8	8	14.0
± 10	5	13	22.8
± 15	5	18	31.6
± 20	6	24	42.1
± 25	4	28	49.1
± 30	5	33	57.9
± 35	6	39	68.4
± 40	5	44	77.2
over ± 40	13	57	100.0
	57		

Mean Variance: 25.7%   Standard Deviation: 16.7%

Minimum Variance: 0.0%   Maximum Variance: 65.6%

Average Under Specified: 27.8%   Average Over Specified: 20.6%

1983
Total Aggregate Quantity
(Asphalt Bitumen)

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	30	30	22.7
± 10	26	56	42.4
± 15	14	70	53.0
± 20	12	82	62.1
± 25	7	89	67.4
± 30	7	96	72.7
± 35	8	104	78.8
± 40	8	112	84.8
over ± 40	20	132	100.0
	132		

Mean Variance: 21.1%   Standard Deviation: 21.6%

Minimum Variance: 0.0%   Maximum Variance: 136.5%

Average Under Specified: 17.2%   Average Over Specified: 24.2%

1984
Total Aggregate Quantity
(Asphalt Bitumen)

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	14	14	15.1
± 10	9	23	24.7
± 15	9	32	34.4
± 20	8	40	43.0
± 25	8	48	51.6
± 30	5	53	57.0
± 35	16	69	74.2
± 40	8	77	82.8
over ± 40	16	93	100.0
	93		

Mean Variance: 29.8% Standard Deviation: 31.3%

Minimum Variance: 0.4% Maximum Variance: 160.5%

Average Under Specified: 19.1% Average Over Specified: 38.2%

1985
Total Aggregate Quantity
(Asphalt Bitumen)

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	34	34	11.0
± 10	51	85	27.6
± 15	39	124	40.3
± 20	27	151	49.0
± 25	26	177	57.5
± 30	29	206	66.9
± 35	21	227	73.7
± 40	15	242	78.6
over ± 40	66	308	100.0
	308		

Mean Variance: 26.2%

Standard Deviation: 22.8%

Minimum Variance: 0.0%

Maximum Variance: 190.3%

Average Under Specified: 2.8%

Average Over Specified: 30.3%

1982-1985
Total Aggregate Quantity
(Asphalt Bitumen)

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	86	86	14.6
± 10	91	177	30.0
± 15	67	244	41.4
± 20	53	297	50.3
± 25	45	342	58.0
± 30	46	388	65.8
± 35	51	439	74.4
± 40	36	475	80.5
over ± 40	115	590	100.0
	590		

Mean Variance: 25.6%

Standard Deviation: 23.7%

Minimum Variance: 0.0%

Maximum Variance: 190.3%

Average Under Specified: 20.8%

Average Over Specified: 29.7%

1982-1985
Total Aggregate Quantity
400 Pounds Per Square
(Asphalt Bitumen)

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	66	66	15.5
± 10	73	139	32.6
± 15	49	188	44.1
± 20	42	230	54.0
± 25	27	257	60.3
± 30	32	289	67.8
± 35	31	320	75.1
± 40	21	341	80.0
over ± 40	85	426	100.0
	426		

Sample Mean: 447.74lbs/sq

Standard Deviation: 138.34lbs/sq

Sample Variance from 400 lb/sq: 25.76%

Standard Deviation of Variance: 25.96%

Minimum Variance: 0.00%

Maximum Variance: 190.25%

Average Under Specified: 17.74%

Average Over Specified: 30.88%

1982-1985
Total Aggregate Quantity
300 Pounds Per Square
(Asphalt Bitumen)

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	4	4	17.4
± 10	4	8	34.8
± 15	5	13	56.5
± 20	1	14	60.9
± 25	1	15	65.2
± 30	1	16	69.6
± 35	3	19	82.6
± 40	1	20	87.0
over ± 40	3	23	100.0
	23		

Sample Mean: 334.82lbs/sq

Standard Deviation: 70.67lbs/sq

Sample Variance from 300 lb/sq: 19.89%

Standard Deviation of Variance: 16.80%

Minimum Variance: 1.17%

Maximum Variance: 65.57%

Average Under Specified: 10.58%

Average Over Specified: 25.87%

C. Coal Tar Analysis Results

Coal Tar Top Pour
1982

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	2	2	6.7
± 10	3	5	16.7
± 15	5	10	33.3
± 20	0	10	33.3
± 25	0	18	33.3
± 30	2	12	40.0
± 35	4	16	53.3
± 40	2	18	60.0
over ± 40	12	30	100.0
	30		

Mean Variance: 38.22% Standard Deviation: 29.26%

Minimum Variance: 0.00% Maximum Variance: 112.00%

Average Under Specified: 21.35% Average Over Specified: 51.13%

Coal Tar Top Pour
1983

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	25	25	20.2
± 10	20	45	36.3
± 15	23	68	54.8
± 20	13	81	65.3
± 25	6	87	70.2
± 30	9	96	77.4
± 35	3	99	79.8
± 40	6	105	84.7
over ± 40	19	124	100.0
	124		

Mean Variance:	29.60%	Standard Deviation:	50.59%
Minimum Variance:	0.14%	Maximum Variance:	318.67%
Average Under Specified:	18.22%	Average Over Specified:	40.26%

Coal Tar Top Pour
1984

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	42	42	11.4
± 10	49	91	24.7
± 15	57	148	40.2
± 20	40	188	51.1
± 25	33	221	60.1
± 30	28	249	67.7
± 35	26	275	74.7
± 40	19	294	79.9
over ± 40	74	368	100.0
	368		

Mean Variance:	36.34%	Standard Deviation.	51.64%
Minimum Variance:	0.00%	Maximum Variance:	365.33%
Average Under Specified:	20.06%	Average Over Specified:	53.53%

Coal Tar Top Pour
1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	13	13	10.2
± 10	20	33	26.0
± 15	11	44	34.6
± 20	12	56	44.1
± 25	14	70	55.1
± 30	14	84	66.1
± 35	6	90	70.9
± 40	10	100	78.7
over ± 40	27	127	100.0
	127		

Mean Variance:	28.79%	Standard Deviation:	27.87%
Minimum Variance:	0.27%	Maximum Variance:	156.57%
Average Under Specified:	26.68%	Average Over Specified:	32.38%

Coal Tar Top Pour
1982-1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	82	82	12.6
± 10	92	174	26.8
± 15	96	270	41.6
± 20	65	335	51.6
± 25	53	388	59.8
± 30	53	441	68.0
± 35	39	480	74.0
± 40	37	517	79.7
over ± 40	132	649	100.0
	649		

Mean Variance: 33.66%

Standard Deviation: 46.89%

Minimum Variance: 0.00%

Maximum Variance: 365.33%

Average Under Specified: 20.94%

Average Over Specified: 46.83%

Coal Tar Interply
1982

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	12	12	30.8
± 10	5	17	43.6
± 15	4	21	53.8
± 20	2	23	59.0
± 25	4	27	69.2
± 30	1	28	71.8
± 35	0	28	71.8
± 40	2	30	76.9
over ± 40	9	39	100.0
	39		

Mean Variance: 21.10% Standard Deviation: 20.63%

Minimum Variance: 0.40% Maximum Variance: 78.50%

Average Under Specified: 5.74% Average Over Specified: 32.96%

Coal Tar Interply
1983

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	17	17	13.6
± 10	15	32	25.6
± 15	16	48	38.4
± 20	7	55	44.0
± 25	6	61	48.8
± 30	9	70	56.0
± 35	6	76	60.8
± 40	6	82	65.6
over ± 40	43	125	100.0
	125		

Mean Variance: 31.05% Standard Deviation: 25.22%

Minimum Variance: 0.00% Maximum Variance: 122.00%

Average Under Specified: 7.18% Average Over Specified: 36.44%

Coal Tar Interply
1984

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	64	64	17.3
± 10	52	116	31.4
± 15	73	189	51.2
± 20	38	227	61.5
± 25	50	277	75.1
± 30	34	311	84.3
± 35	21	332	90.0
± 40	19	351	95.1
over ± 40	18	369	100.0
	369		

Mean Variance: 17.52% Standard Deviation: 12.43%

Minimum Variance: 0.00% Maximum Variance: 76.40%

Average Under Specified: 16.20% Average Over Specified: 19.09%

Coal Tar Interply
1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	21	21	14.9
± 10	27	48	34.0
± 15	8	56	39.7
± 20	15	71	50.4
± 25	10	81	57.4
± 30	12	93	66.0
± 35	9	102	72.3
± 40	11	113	80.1
over ± 40	28	141	100.0
	141		

Mean Variance: 24.89%   Standard Deviation: 20.11%

Minimum Variance: 0.00%   Maximum Variance: 97.00%

Average Under Specified: 12.16%   Average Over Specified: 29.10%

Coal Tar Interply
1982-1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	114	114	1.98
± 10	99	213	31.6
± 15	101	314	46.6
± 20	62	376	55.8
± 25	70	446	66.2
± 30	56	502	74.5
± 35	36	538	79.8
± 40	38	576	85.5
over ± 40	98	674	100.0
	674		

Mean Variance: 21.78% Standard Deviation: 18.38%

Minimum Variance: 0.00% Maximum Variance: 122.00%

Average Under Specified: 14.29% Average Over Specified: 26.95%

1982 Headlap
(Coal Tar Bitumen)

Difference From Specified (inch)	Number Samples (Frequency)	Cummulative Number Samples	Cummulative Percent Within Difference
under ± 0.25	8	8	20.5
± 0.50	9	17	43.6
± 0.75	2	19	48.7
± 1.00	4	23	59.0
± 1.25	2	25	64.1
over ± 1.25	14	39	100.0
	39		

Mean Headlap:	2.46 inches	Standard Deviation:	1.31 inches
Mean Difference:	1.04 inches	Standard Deviation: of Difference	0.90 inch
Minimum Variance:	0.00 inch	Maximum Variance:	3.40 inches
Average Under Specified:	0.67 inch	Average Over Specified:	1.33 inches

1983 Headlap
(Coal Tar Bitumen)

Difference From Specified (inch)	Number Samples (Frequency)	Cummulative Number Samples	Cummulative Percent Within Difference
under ± 0.25	37	37	30.1
± 0.50	28	65	52.8
± 0.75	16	81	65.9
± 1.00	15	96	78.0
± 1.25	7	103	83.7
over ± 1.25	20	123	100.0
	123		

Mean Headlap: 1.95 inches

Standard Deviation: 0.88 inch

Mean Difference: 0.66 inch

Standard Deviation: of Difference 0.58 inch

Minimum Variance: 0.00 inch

Maximum Variance: 2.40 inches

Average Under Specified: 0.62 inch

Average Over Specified: 0.72 inch

1984 Headlap
(Coal Tar Bitumen)

Difference From Specified (inch)	Number Samples (Frequency)	Cummulative Number Samples	Cummulative Percent Within Difference
under ± 0.25	136	136	37.6
± 0.50	118	254	70.2
± 0.75	31	285	78.7
± 1.00	33	318	87.8
± 1.25	9	327	90.3
over ± 1.25	35	362	100.0
	362		

Mean Headlap:	2.03 inches	Standard Deviation:	0.83 inch
Mean Difference:	0.53 inch	Standard Deviation: of Difference	0.64 inch
Minimum Variance:	0.00 inch	Maximum Variance:	5.60 inches
Average Under Specified:	0.43 inch	Average Over Specified:	0.68 inch

1985 Headlap
(Coal Tar Bitumen)

Difference From Specified (inch)	Number Samples (Frequency)	Cummulative Number Samples	Cummulative Percent Within Difference
under ± 0.25	43	43	31.2
± 0.50	42	85	61.6
± 0.75	8	93	67.4
± 1.00	16	109	79.0
± 1.25	4	113	81.9
over ± 1.25	25	138	100.0
	138		

Mean Headlap: 2.17 inches

Standard Deviation: 1.20 inches

Mean Difference: 0.75 inch

Standard Deviation of Difference: 0.95 inch

Minimum Variance: 0.00 inch

Maximum Variance: 5.90 inches

Average Under Specified: 0.64 inch

Average Over Specified: 0.83 inch

1982-1985 Headlap
(Coal Tar Bitumen)

Difference From Specified (inch)	Number Samples (Frequency)	Cummulative Number Samples	Cummulative Percent Within Difference
under ± 0.25	224	224	33.8
± 0.50	197	421	63.6
± 0.75	57	478	72.2
± 1.00	68	546	82.5
± 1.25	22	568	85.8
over ± 1.25	94	662	100.0
	662		

Mean Headlap: 2.07 inches

Standard Deviation: 0.97 inch

Mean Difference: 0.63 inch

Standard Deviation of Difference: 0.74 inch

Minimum Variance: 0.00 inch

Maximum Variance: 5.90 inches

Average Under Specified: 0.51 inch

Average Over Specified: 0.77 inch

Total Aggregate Quantity
(Coal Tar Bitumen)
1982

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	5	5	20.0
± 10	1	6	24.0
± 15	2	8	32.0
± 20	6	14	56.0
± 25	1	15	60.0
± 30	4	19	76.0
± 35	0	19	76.0
± 40	4	23	92.0
over ± 40	2	25	100.0
	25		

Mean Variance:	22.30%	Standard Deviation:	16.44%
Minimum Variance:	1.63%	Maximum Variance:	63.03%
Average Under Specified:	25.70%	Average Over Specified:	20.03%

Total Aggregate Quantity
(Coal Tar Bitumen)
1983

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	4	4	14.3
± 10	2	6	21.4
± 15	2	8	28.6
± 20	3	11	39.3
± 25	4	15	53.6
± 30	0	15	53.6
± 35	1	16	57.1
± 40	3	19	67.9
over ± 40	9	28	100.0
	28		

Mean Variance: 39.00%　Standard Deviation: 36.75%

Minimum Variance: 0.35%　Maximum Variance: 130.68%

Average Under Specified: 16.50%　Average Over Specified: 49.67%

Total Aggregate Quantity
(Coal Tar Bitumen)
1984

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	10	10	9.3
± 10	13	23	21.5
± 15	8	31	29.0
± 20	9	40	37.4
± 25	8	48	44.9
± 30	6	54	50.5
± 35	6	60	56.1
± 40	10	70	65.4
over ± 40	37	107	100.0
	107		

Mean Variance: 34.89%   Standard Deviation: 27.05%

Minimum Variance: 0.00%   Maximum Variance: 115.50%

Average Under Specified: 23.07%   Average Over Specified: 41.40%

Total Aggregate Quantity
(Coal Tar Bitumen)
1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	0	0	0
± 10	2	2	6.5
± 15	1	3	9.7
± 20	5	8	25.8
± 25	4	12	38.7
± 30	0	12	38.7
± 35	4	16	51.6
± 40	1	17	54.8
over ± 40	14	31	100.0
	31		

Mean Variance: 39.77%

Standard Deviation: 24.75%

Minimum Variance: 6.65%

Maximum Variance: 93.58%

Average Under Specified: 29.22%

Average Over Specified: 42.30%

Total Aggregate Quantity
(Coal Tar Bitumen)
1982-1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	19	19	9.9
± 10	18	37	19.4
± 15	13	50	26.2
± 20	23	73	38.2
± 25	17	90	47.1
± 30	10	100	52.4
± 35	11	111	58.1
± 40	18	129	67.5
over ± 40	62	191	100.0
	191		

Mean Variance: 34.64%　　Standard Deviation: 27.54%

Minimum Variance: 0.00%　　Maximum Variance: 130.68%

Average Under Specified: 23.14%　　Average Over Specified: 40.30%

Aggregate Quantity - Coal Tar
400 Pounds Per Square
1932-1985

Percent Variance From Specified	Number Samples	Cummulative Number Samples	Cummulative Percent Within Variance
under ± 5	16	16	10.0
± 10	15	31	19.4
± 15	12	43	26.9
± 20	19	62	38.8
± 25	15	77	48.1
± 30	8	85	53.1
± 35	11	96	60.0
± 40	14	110	68.8
over ± 40	50	160	100.0
	160		

Sample Mean: 489.47 lbs/sq   Standard Deviation: 152.12 lbs/sq

Sample Variance: 34.22%   Standard Deviation: of Variance 27.77%

Minimum Variance: 0.00%   Maximum Variance: 130.68%

Average Under Specified: 18.59%   Average Over Specified: 41.53%

D. Asphalt Sample Data

ASPHALT TEST RESULTS 1982

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Blyth-	120	124.7	20	35.4	2	2.0
ville	60	38.9	20	31.0	2	2.0
	60	70.7	20	36.5	2	4.0
	60	75.8	20	25.8	2	3.7
	60	34.4	20	24.8	2	2.6
	60	49.2	20	21.9	2	1.3
	60	55.2	20	25.7	2	2.4
	60	80.1	20	53.0	2	4.6
	60	93.3	20	40.9	2	7.8
	60	107.5	20	41.9	2	0.2
	60	101.4	20	35.8	2	0.4
	120	170.1	20	22.0	2	2.7
	120	184.9	20	21.0	2	2.8
	120	189.3	20	24.0	2	-
March	60	76.0	25	22.1	2	2.6
	60	155.0	25	27.3	2	2.2
	60	96.0	25	23.5	2	2.0
	60	91.8	25	24.3	2	2.2
	60	88.3	25	26.7	2	2.0
	60	92.3	25	24.3	2	2.2
	60	113.0	25	16.4	2	2.1
	60	78.7	25	22.4	2	1.9
	60	197.1	30	29.0	2	0.0
	100	93.8	25	16.3	2	1.9
	100	124.8	25	24.2	2	2.2
	110	178.0	25	24.2	2	2.3
	110	119.9	25	23.2	2	1.6
	110	190.5	30	43.8	2	1.8
	110	198.7	25	29.3	2	2.4
	110	115.2	25	30.4	2	2.0
	110	123.2	25	34.1	2	1.7
	110	165.3	25	28.0	2	2.2
	110	54.3	25	20.5	2	2.8
	110	108.1	25	24.7	2	4.4
	110	112.8	25	20.7	2	2.7
	110	80.8	25	26.8	2	1.8
	110	82.7	25	22.5	2	2.3
	110	122.8	25	24.2	2	1.9
	110	84.0	25	25.8	2	2.1
	110	126.3	25	22.1	2	1.9
	110	167.4	30	37.7	2	1.3
	110	176.8	30	32.9	2	2.4
Beale	60	53.6	25	31.1	2	1.8
	60	47.0	25	33.4	2	1.7
	60	51.3	25	33.8	2	1.6
	60	60.7	25	31.6	2	1.5

ASPHALT TEST RESULTS 1982

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Beale	60	41.9	25	35.0	2	1.8
	60	75.6	25	30.2	2	1.4
	60	35.5	25	34.1	2	1.4
Loring	60	69.6	30	44.6	2	3.6
	60	92.2	30	29.4	2	4.6
	60	51.1	30	23.9	2	0.8
	60	103.1	30	25.3	2	2.7
	60	139.5	30	24.9	2	2.5
	60	65.0	30	29.3	2	2.3
Vanden-	-	-	25	21.2	2	2.0
berg	-	-	25	18.6	2	-
	-	-	25	34.3	2	2.5
	-	-	25	27.8	2	2.3
	-	-	25	24.7	2	4.1
	60	61.4	25	17.5	2	1.5
	60	62.5	25	18.3	2	1.0
	60	72.8	25	18.1	2	-
	60	64.3	25	31.2	2	1.2
	-	-	25	23.1	2	-
Unknown	60	34.0	25	29.3	2	6.0
	60	50.2	25	25.5	2	2.3
	-	-	25	26.4	2	1.8

ASPHALT TEST RESULTS 1983

BASE	FLOOD(lbs/sq) REQUIRED	ACTUAL	INTERPLY(lbs/sq) REQUIRED	ACTUAL	HEADLAP(inch) REQUIRED	ACTUAL
March	110	111.8	25	24.7	2	1.8
	110	126.5	25	28.2	2	1.8
	110	112.1	25	25.5	2	1.8
	110	207.0	30	30.9	2	2.2
	110	297.9	30	31.6	2	2.7
	110	198.3	25	28.8	2	2.1
	110	182.1	25	28.2	2	2.2
	110	162.9	30	27.2	2	1.0
	110	200.3	30	34.3	2	1.9
	110	215.8	30	26.5	2	2.2
	110	144.0	25	30.5	2	2.5
	110	175.5	25	25.0	2	1.8
	110	142.0	30	32.9	2	2.6
	110	60.3	30	24.4	2	0.8
	110	156.2	30	38.5	2	2.9
	110	86.9	30	26.7	2	1.0
	110	95.7	30	37.6	2	3.4
	110	72.6	30	26.2	2	2.4
	110	105.2	30	29.3	2	1.5
	110	244.9	30	30.4	2	2.1
	110	79.6	30	29.5	2	2.4
	110	177.8	30	32.4	2	1.8
	110	93.5	30	29.6	2	2.1
	110	139.0	30	31.8	2	2.0
	110	70.4	30	27.3	2	2.4
	110	109.9	30	27.8	2	2.4
	110	109.3	30	22.0	2	1.3
	110	158.6	30	32.8	2	1.5
	110	83.9	30	26.2	2	1.6
	110	163.0	30	29.8	2	1.3
	110	78.4	30	30.8	2	2.6
	110	102.4	30	23.6	2	1.6
	110	67.9	30	26.5	2	2.4
	110	137.2	30	32.7	2	2.4
	110	113.7	30	27.6	2	2.4
	110	70.9	30	29.3	2	1.8
	110	65.6	30	27.4	2	1.6
	110	96.5	30	31.6	2	1.8
	60	42.1	23	24.5	2	2.9
	60	67.4	23	23.8	2	3.2
	60	52.1	25	22.3	2	1.8
	60	48.9	25	19.8	2	2.9
March	60	48.9	25	25.8	2	1.8
	60	55.8	25	32.0	2	1.4
	60	65.2	25	24.0	2	1.0
	60	43.9	25	22.1	2	1.9
	60	41.2	25	22.3	2	2.9
Pease	60	76.9	22	18.8	2	1.7
	60	39.2	22	18.8	2	2.4

ASPHALT TEST RESULTS 1983

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Pease	60	39.6	22	21.1	2	1.8
	60	49.5	22	20.3	2	1.9
	60	23.3	22	22.3	2	2.7
	60	59.0	22	19.8	2	1.0
	60	125.5	22	28.2	2	1.9
	60	32.5	22	28.1	2	1.9
K.I.	60	17.9	30	16.2	2	2.4
Sawyer	60	73.0	30	27.4	2	2.5
	60	73.0	30	27.4	2	2.5
	60	64.9	30	29.3	2	2.4
	60	48.5	30	33.8	2	2.1
	60	67.8	30	30.7	2	3.2
	60	86.0	30	36.1	2	2.6
	60	51.4	30	30.4	2	1.9
	60	114.4	30	33.8	2	2.2
	60	95.0	30	28.6	2	2.1
	60	76.0	30	26.9	2	2.5
	60	51.1	30	29.2	2	2.0
	60	103.5	30	30.1	2	2.0
	60	69.8	30	22.0	2	1.5
	60	100.9	30	29.5	2	1.8
	60	55.3	30	25.2	2	2.1
	60	80.9	30	32.0	2	2.0
	60	46.1	30	30.5	2	2.0
	60	58.3	30	36.3	2	1.8
	60	54.2	30	32.2	2	1.5
	60	41.8	30	29.5	2	2.2
	60	42.8	30	29.7	2	1.8
	60	84.4	30	30.1	2	1.8
	60	55.0	30	28.8	2	2.1
	60	53.0	30	27.9	2	1.8
	60	53.4	30	33.8	2	-
	60	63.6	30	28.3	2	1.9
	60	44.9	30	33.5	2	1.9
	60	50.0	30	27.4	2	2.5
	60	62.5	30	35.2	2	1.8
	60	52.5	30	30.3	2	2.0
	60	51.0	30	27.2	2	2.2
	60	55.2	30	31.6	2	2.2
	60	55.5	30	29.8	2	2.6
	60	63.5	30	34.3	2	1.3
	60	53.6	30	23.9	2	3.3
	60	67.9	30	28.1	2	1.9
	60	51.7	30	27.1	2	1.5
	60	55.6	30	28.0	2	1.9
	60	40.6	30	26.8	2	1.4
	60	64.9	30	25.5	2	2.0
	60	63.7	30	36.0	2	2.8

ASPHALT TEST RESULTS 1983

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
K.I.	60	52.7	30	32.2	2	2.0
Sawyer	60	55.9	30	26.3	2	2.2
	60	59.0	30	31.1	2	2.5
	60	51.0	30	27.7	2	2.8
	60	63.1	30	32.7	2	1.5
	60	48.3	30	28.9	2	0.9
	60	43.3	30	30.5	2	0.7
	60	57.8	30	30.9	2	1.7
	60	60.8	30	29.2	2	2.0
	60	62.5	30	29.5	2	1.6
	60	54.0	30	32.3	2	1.8
	60	51.0	30	26.2	2	1.3
	60	116.4	30	33.6	2	2.1
Seymour	60	156.5	25	33.6	2	2.8
Johnson	60	56.7	25	24.8	2	2.9
	60	63.5	25	25.2	2	1.6
	60	82.3	25	23.2	2	3.0
	60	79.5	25	27.5	2	0.4
	60	112.4	25	22.8	2	1.3
	60	105.1	25	24.1	2	2.0
Vanden-	60	60.0	-	-	2	2.4
berg	60	51.0	-	-	2	1.9
	60	61.3	-	-	2	2.1
	60	82.2	-	-	2	-
	60	78.1	25	25.4	2	2.5
	60	42.1	25	23.3	2	1.9
	60	41.1	25	25.3	2	2.0
Little	60	49.0	23	27.0	2	2.0
Rock	60	36.0	23	40.7	2	2.3
	60	59.0	23	35.3	2	2.3
	60	57.0	23	25.7	2	2.4
	60	52.0	23	18.0	2	2.4
	60	80.0	23	27.3	2	2.5
	60	122.0	23	37.7	2	0.0
	60	84.0	23	35.3	2	2.2
	60	85.0	23	29.3	2	3.4
	75	51.0	25	32.5	2	1.8
	60	58.0	23	27.3	2	2.3
	60	64.0	23	21.0	2	1.8
	60	25.0	23	32.1	2	1.6
	60	72.0	23	20.7	2	0.9
Unknown	60	51.2	25	30.5	2	2.9
	60	52.8	25	28.2	2	5.5
	60	58.3	25	39.6	2	5.1
	60	57.8	25	32.7	2	2.4
	60	69.4	25	33.4	2	3.3
	60	71.4	25	31.2	2	3.6
	60	84.9	25	29.0	2	4.3

ASPHALT TEST RESULTS 1983

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	37.8	25	37.7	2	1.4
	60	49.2	25	20.3	2	6.6
	60	50.4	25	23.6	2	3.5
	60	52.9	25	26.4	2	4.3
	60	48.5	25	21.5	2	6.1
	60	29.9	25	30.2	2	1.3
	60	43.1	25	31.8	2	1.8
	60	39.2	25	32.8	2	1.5
	60	22.4	25	29.7	2	2.6
	60	31.0	25	30.3	2	1.3
	60	56.0	25	32.5	2	1.5
	60	88.6	25	33.3	2	1.9
	60	35.7	25	25.8	2	1.3
	60	28.0	25	29.5	2	1.6
	-	-	25	33.7	2	2.0
	-	-	25	23.1	2	1.1
	-	-	25	26.7	2	2.0
	-	-	25	18.5	2	2.0
	-	-	25	24.7	2	3.5
	60	48.5	25	32.2	2	2.1
	-	-	25	22.6	2	2.0
	60	28.3	25	28.0	2	2.1
	60	29.7	25	27.8	2	2.6
	60	29.1	25	32.9	2	1.9
	-	-	25	29.3	2	2.0
	-	-	25	23.8	2	2.6
	-	-	25	22.8	2	4.0
	-	-	25	24.6	2	2.0
	-	-	25	24.2	2	1.9
	-	-	25	28.9	2	2.3
	-	-	25	26.9	2	2.3
	-	-	25	24.2	2	2.8
	-	-	25	24.6	2	2.0
	-	-	25	23.9	2	2.3
	-	-	25	23.4	2	0.0
	-	-	25	32.6	2	2.1
	-	-	25	29.7	2	0.0
	-	-	25	18.0	2	0.0
	-	-	25	19.4	2	0.0
	-	-	25	21.2	2	0.0
	-	-	25	18.1	2	0.0
	-	-	25	30.3	2	2.4
	-	-	25	25.7	2	1.9
	60	22.9	25	24.4	2	2.3
	60	74.8	25	34.9	2	1.4
	60	85.9	25	43.6	2	0.9
	60	49.6	25	35.8	2	2.0
	60	58.6	25	28.2	2	1.5

ASPHALT TEST RESULTS 1983

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	56.1	25	23.8	2	2.3
	60	85.5	25	25.8	2	2.0
	60	57.1	25	25.3	2	1.4
	60	54.0	25	31.4	2	2.0
	60	51.2	25	30.5	2	2.9
	60	68.3	25	31.3	2	2.3
	60	47.1	25	31.7	2	1.9
	60	88.2	25	26.3	2	1.3
	60	54.7	25	21.4	2	1.5
	60	68.6	25	32.8	2	1.8
	60	54.9	25	31.4	2	2.3
	60	65.9	25	24.5	2	2.1
	60	63.4	25	27.4	2	3.3
	60	63.9	25	24.4	2	2.9
	60	61.7	25	33.5	2	1.3
	60	59.8	25	24.2	2	1.5
	60	45.4	25	33.9	2	1.8
	60	39.3	25	24.8	2	2.3
	60	51.8	25	28.4	2	2.4
	60	55.1	25	31.8	2	2.3
	60	84.7	25	25.0	2	1.4
	60	41.4	25	38.5	2	2.0
	60	53.2	25	20.9	2	2.5
	60	78.9	25	27.9	2	2.0
	60	39.3	25	27.1	2	2.5
	60	70.8	25	26.0	2	2.0
	60	54.2	25	39.6	2	2.1
	60	53.2	25	25.8	2	1.7
	60	55.6	25	39.9	2	2.1
	60	51.4	25	24.0	2	4.3
	60	62.7	25	30.0	2	6.1
	60	44.1	25	31.7	2	1.8
	60	60.0	25	29.2	2	2.0
	60	30.7	25	28.3	2	1.7
	60	30.1	25	25.4	2	1.9
	60	42.2	25	20.6	2	1.8
	-	-	25	24.3	2	1.6
	-	-	25	22.6	2	1.6
	60	46.6	25	27.9	2	2.1
	60	41.5	25	23.7	2	2.0
	60	75.0	25	21.7	2	2.2
	60	94.1	25	25.8	2	0.0
	60	45.4	25	30.5	2	1.6
	60	43.1	25	35.8	2	0.3
	60	50.2	25	24.7	2	0.8
	60	36.7	25	29.9	2	0.9
	60	56.0	25	27.6	2	2.3
	-	-	25	29.6	2	2.4

ASPHALT TEST RESULTS 1983

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	-	-	25	26.1	2	2.5
	-	-	25	24.8	2	2.4
	-	-	25	22.2	2	2.4
	-	-	25	21.8	2	2.3
	-	-	25	21.5	2	2.5
	-	-	25	25.8	2	3.0
	-	-	25	22.3	2	1.6
	-	-	25	23.8	2	1.8
	-	-	25	25.1	2	1.6
	-	-	25	21.7	2	1.5
	-	-	25	32.7	2	2.5
	-	-	25	33.6	2	2.4
	-	-	25	28.7	2	2.4
	-	-	25	22.5	2	2.4
	-	-	25	29.5	2	2.5
	-	-	25	22.7	2	2.5
	-	-	25	27.0	2	2.3
	-	-	25	36.7	2	2.5
	-	-	25	25.9	2	2.6
	-	-	25	33.5	2	2.1
	-	-	25	30.5	2	2.6
	-	-	25	30.7	2	2.5
	-	-	25	20.7	2	3.4
	-	-	25	25.3	2	2.0
	-	-	25	23.1	2	1.6
	60	60.1	25	17.3	2	1.9
	60	33.0	25	29.7	2	1.9
	60	53.3	25	30.7	2	2.1
	60	79.3	25	32.5	2	2.3
	60	59.5	25	25.7	2	2.3
	60	53.8	25	32.9	2	2.0
	60	44.5	25	29.7	2	2.1
	60	66.7	25	31.9	2	2.3
	60	33.0	25	28.7	2	1.9
	60	48.0	25	31.3	2	2.1
	60	38.6	25	27.6	2	2.0
	60	28.0	25	28.7	2	2.0
	60	28.0	25	23.5	2	2.4
	60	38.5	25	23.4	2	1.9
	60	31.5	25	23.0	2	2.0
	60	48.6	25	27.4	2	0.7
	60	61.7	25	33.3	2	1.0
	60	56.1	25	24.9	2	2.4
	60	64.7	25	22.7	2	0.3
	60	70.0	25	18.0	2	1.9
	60	27.2	25	32.1	2	1.9
	60	98.0	25	26.3	2	3.0
	60	69.5	25	34.4	2	2.3

ASPHALT TEST RESULTS 1983

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	67.0	25	37.0	2	2.0
	60	59.5	25	28.4	2	1.6
	60	40.6	25	21.1	2	1.9
	60	35.7	25	27.8	2	1.5
	60	45.3	25	18.5	2	2.5
	60	53.2	25	20.6	2	2.5
	60	39.5	25	23.2	2	0.9
	60	45.2	25	18.7	2	5.3
	60	51.9	25	16.0	2	2.5
	60	42.7	25	15.8	2	2.8
	60	60.9	25	18.9	2	1.8
	60	57.2	25	22.6	2	1.6
	60	45.9	25	17.4	2	2.9
	60	28.9	25	23.0	2	0.0
	60	39.7	25	25.4	2	2.0
	60	19.7	25	24.5	2	2.3
	60	76.9	25	20.3	2	3.8
	60	19.9	25	22.4	2	2.5
	60	19.9	25	19.8	2	2.5
	60	21.3	25	24.5	2	2.0
	60	20.3	25	21.7	2	2.4
	60	27.3	25	16.0	2	2.1
	60	75.1	25	21.4	2	2.1
	60	90.1	25	26.7	2	1.8
	60	28.1	25	29.1	2	2.4
	60	38.4	25	18.8	2	2.3
	60	30.0	25	22.0	2	2.3
	60	30.2	25	19.5	2	2.0
	60	52.6	25	22.4	2	2.5
	60	61.3	25	16.9	2	2.0
	60	59.4	25	20.8	2	2.0
	60	83.3	25	24.3	2	2.0
	60	58.9	25	18.4	2	2.0
	60	76.0	25	24.9	2	1.9
	60	74.1	25	18.1	2	2.0
	60	63.7	25	13.8	2	1.9
	60	61.0	25	21.9	2	0.5
	60	78.2	25	27.4	2	1.5
	60	94.3	25	26.0	2	1.0
	60	96.7	25	27.6	2	1.6
	60	63.4	25	26.5	2	1.4
	60	95.7	25	29.5	2	1.6
	60	70.8	25	24.6	2	2.0
	60	60.7	25	31.6	2	1.3
	60	70.9	25	24.9	2	1.9
	60	54.7	25	30.2	2	1.1
	60	71.8	25	32.7	2	1.3
	60	89.7	25	29.0	2	1.4

ASPHALT TEST RESULTS 1983

	FLOOD(lbs/sq)		INTERPLY(lbs/sq)		HEADLAP(inch)	
BASE	REQUIRED	ACTUAL	REQUIRED	ACTUAL	REQUIRED	ACTUAL
Unknown	60	76.7	25	32.6	2	0.8
	60	74.8	25	25.7	2	2.0
	60	78.2	25	27.4	2	0.0
	60	68.2	25	29.0	2	4.3
	60	63.2	25	35.8	2	4.0
	60	74.1	25	26.2	2	3.9
	60	62.3	25	35.6	2	2.5
	60	54.1	25	26.4	2	3.6
	60	98.2	25	33.9	2	1.4
	60	96.8	25	26.6	2	0.8
	60	47.7	25	24.2	2	0.0
	60	55.0	25	31.6	2	4.5
	60	62.7	25	30.0	2	6.1
	60	45.0	25	26.4	2	6.0
	60	44.1	25	29.0	2	2.0
	60	38.1	25	30.0	2	2.4
	60	65.7	25	33.6	2	4.0
	60	62.6	25	32.6	2	3.9
	60	29.5	25	34.8	2	1.8
	60	69.2	25	39.4	2	0.1
	60	40.0	25	19.9	2	0.0
	60	21.4	25	17.2	2	1.6
	60	44.1	25	17.9	2	1.4
	60	37.0	25	25.4	2	2.3
	60	21.1	25	38.4	2	1.4
	60	44.9	25	28.2	2	1.4
	60	79.8	25	19.7	2	0.5
	60	66.9	25	16.7	2	0.8
	60	70.7	25	17.1	2	0.0
	60	28.1	25	40.1	2	4.0
	60	80.5	25	31.6	2	5.3
	60	90.7	25	21.0	2	2.3
	60	66.1	25	37.8	2	2.8
	60	75.5	25	25.4	2	3.0
	60	15.9	25	25.8	2	1.6
	60	26.9	25	16.2	2	5.0
	60	47.1	25	32.2	2	2.5
	60	51.1	25	29.4	2	0.0
	60	41.3	25	21.3	2	0.0
	60	21.5	25	24.3	2	2.5
	60	41.3	25	31.4	2	0.0
	60	48.7	25	25.4	2	1.1
	60	51.0	25	19.6	2	2.0
	60	55.9	25	24.1	2	3.9
	60	24.3	25	22.7	2	1.9
	60	19.3	25	24.7	2	1.6
	60	30.6	25	14.9	2	2.6
	60	28.1	25	19.6	2	2.3

ASPHALT TEST RESULTS 1983

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	28.9	25	19.2	2	2.6
	60	31.0	25	39.7	2	2.1

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
March	60	73.8	25	27.8	2	2.1
	60	68.8	25	23.9	2	1.6
	60	73.1	25	29.3	2	4.8
	60	57.4	25	26.9	2	2.7
	60	84.3	25	23.5	2	2.4
	60	135.4	25	26.6	2	2.9
	60	123.8	25	27.4	2	2.7
	60	83.8	25	24.9	2	2.1
	60	78.1	25	35.4	2	2.0
	60	74.8	25	31.2	2	1.3
	60	110.3	25	33.3	2	2.1
	60	51.6	25	36.1	2	3.5
	60	59.0	25	29.8	2	2.7
	60	65.8	25	27.9	2	3.2
	60	48.3	25	25.7	2	3.3
	60	56.6	25	28.5	2	2.3
	60	52.0	25	28.5	2	1.8
Dover	60	39.8	25	31.6	2	1.9
	60	79.4	25	30.7	2	1.2
	60	92.4	25	26.1	2	0.8
	60	95.7	25	32.2	2	0.0
	60	145.0	25	24.1	2	2.4
	60	60.2	25	32.6	2	1.2
	60	136.2	25	31.2	2	2.3
	60	76.9	25	34.8	2	2.8
	60	52.9	25	23.2	2	2.2
	60	65.0	25	22.9	2	2.0
	60	61.1	25	21.7	2	3.2
	60	89.3	25	23.3	2	2.0
	75	79.7	25	29.6	2	1.3
	-	-	25	23.4	2	2.5
	-	-	25	26.2	2	2.5
	-	-	25	27.5	2	2.6
	-	-	25	24.6	2	3.8
	60	36.7	25	35.7	2	2.5
	60	56.0	25	38.8	2	2.6
	60	37.8	25	32.8	2	1.1
	60	49.3	25	41.9	2	3.4
	60	347.4	25	40.9	2	1.6
	60	37.2	25	34.6	2	5.2
	60	49.2	25	33.3	2	3.7
	60	64.5	25	40.6	2	3.1
	75	41.6	25	25.7	2	1.5
	75	51.9	25	29.9	2	8.7
	75	104.3	25	34.1	2	3.9
	75	74.1	25	36.2	2	1.5
O'Hare	-	-	23	20.5	2	2.8
	-	-	23	22.6	2	1.9

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
O'Hare	-	-	23	18.2	2	2.5
	-	-	23	19.0	2	2.2
	-	-	23	18.3	2	2.0
Loring	120	209.0	30	27.3	2	2.2
	120	263.0	30	29.3	2	0.4
	120	92.0	30	31.5	2	2.4
	120	177.0	30	31.3	2	1.2
	60	60.0	30	29.5	2	0.9
	60	74.0	30	40.5	2	2.3
	120	124.0	30	30.8	2	1.3
	120	157.0	30	33.3	2	1.7
	120	169.0	30	25.3	2	1.5
	120	190.0	30	24.3	2	0.6
McConnell	60	73.0	23	29.6	2	5.7
	60	64.0	23	24.2	2	3.6
	60	55.0	23	24.5	2	4.0
	60	229.0	23	21.0	2	1.7
	60	118.0	23	20.0	2	3.9
	60	105.0	23	22.5	2	2.9
	60	45.0	23	25.5	2	4.0
Andersen	60	76.0	25	31.3	2	0.8
	60	276.0	25	31.3	2	1.0
	60	151.0	25	25.5	2	1.2
	60	257.0	25	24.5	2	0.8
	60	178.0	25	28.0	2	1.9
	60	258.0	25	30.3	2	1.7
	60	133.0	25	27.8	2	1.9
	60	192.0	25	22.8	2	1.5
	60	153.0	25	20.8	2	1.1
	60	80.0	25	18.3	2	4.1
	60	64.0	25	22.0	2	2.0
	60	89.0	25	23.8	2	1.6
	60	89.0	25	30.3	2	2.2
	60	218.0	25	25.0	2	1.8
	60	107.0	25	32.0	2	2.3
	60	113.0	25	30.0	2	2.4
	60	95.0	25	38.4	2	1.8
	60	95.0	25	38.4	2	1.8
	60	146.0	25	44.3	2	2.0
	60	152.0	25	21.6	2	2.0
	75	232.0	25	26.7	2	2.3
	75	253.0	25	27.0	2	3.5
	75	114.0	25	28.0	2	1.3
	75	299.0	25	32.0	2	3.3
	75	212.0	25	24.4	2	1.4
	75	229.0	25	29.3	2	1.4
	75	197.0	25	23.3	2	1.2
	75	156.0	25	26.3	2	1.7

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Griffiss	60	57.0	30	29.5	2	0.6
	60	93.0	30	32.3	2	0.2
	60	77.0	30	24.7	2	1.7
Vanden-burg	-	-	30	27.0	2	1.8
	-	-	30	34.0	2	1.9
	-	-	30	17.0	2	2.3
	-	-	30	26.0	2	2.1
	-	-	30	30.0	2	1.9
	60	57.0	25	22.0	2	1.8
	60	59.0	25	25.3	2	1.9
	60	51.0	25	23.0	2	1.5
	60	24.0	25	23.3	2	2.2
	60	73.0	25	18.4	2	1.4
Unknown	60	45.4	25	26.5	2	4.1
	60	69.4	25	34.1	2	3.0
	60	56.6	25	27.8	2	3.6
	60	53.4	25	27.7	2	3.8
	60	49.1	25	28.1	2	2.1
	60	47.1	25	27.3	2	3.0
	60	51.8	25	26.2	2	3.3
	60	49.0	25	30.2	2	3.9
	60	42.9	25	29.1	2	3.8
	60	83.5	25	25.3	2	3.0
	60	48.1	25	23.7	2	1.5
	60	42.7	25	26.7	2	1.8
	60	45.8	25	28.2	2	1.4
	60	40.3	25	27.0	2	2.1
	60	53.2	25	22.0	2	2.0
	60	78.8	25	32.5	2	1.8
	60	60.9	25	18.6	2	3.0
	-	-	25	23.3	2	2.0
	60	55.3	25	24.0	2	1.8
	60	52.6	25	22.8	2	3.0
	60	63.9	25	26.6	2	1.3
	60	51.1	25	17.1	2	1.5
	60	58.2	25	24.3	2	0.9
	60	43.2	25	27.8	2	3.1
	60	80.2	25	30.8	2	3.1
	-	-	25	23.0	2	2.4
	-	-	25	21.3	2	2.3
	-	-	25	30.0	2	2.0
	60	72.7	25	26.8	2	2.2
	60	59.0	25	26.5	2	3.4
	60	61.0	25	26.2	2	3.9
	-	-	25	27.6	2	1.9
	-	-	25	28.1	2	3.4
	-	-	25	40.7	2	1.6
	-	-	25	44.9	2	1.6

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	-	-	25	40.7	2	2.6
	60	33.3	25	33.3	2	2.4
	-	-	25	28.8	2	0.0
	-	-	25	46.8	2	1.5
	-	-	25	43.9	2	1.5
	-	-	25	46.7	2	1.5
	-	-	25	39.8	2	2.6
	60	76.9	25	29.7	2	0.8
	60	88.0	25	29.8	2	3.9
	60	71.5	25	25.6	2	3.3
	60	92.1	25	22.4	2	2.8
	60	95.6	25	30.8	2	1.9
	-	-	25	36.0	2	0.0
	60	61.7	25	18.8	2	2.4
	60	68.8	25	18.0	2	3.0
	60	84.8	25	31.6	2	2.3
	60	54.8	25	26.7	2	1.5
	60	71.3	25	19.0	2	1.3
	60	75.1	25	25.0	2	2.3
	60	63.4	25	22.2	2	1.9
	60	53.2	25	31.7	2	3.0
	60	71.0	25	31.8	2	1.6
	60	59.5	25	35.7	2	1.3
	60	58.3	25	18.3	2	1.8
	60	53.2	25	40.1	2	1.9
	60	85.5	25	33.6	2	1.4
	60	52.0	25	30.0	2	2.4
	60	82.4	25	36.0	2	1.9
	60	58.7	25	36.0	2	1.3
	60	57.9	25	17.1	2	2.0
	60	56.0	25	28.0	2	2.0
	60	59.7	25	21.4	2	1.8
	60	85.1	25	26.7	2	2.0
	60	62.9	25	34.0	2	1.9
	60	65.5	25	27.9	2	2.0
	60	88.6	25	30.7	2	1.9
	60	72.0	25	35.7	2	1.9
	60	48.7	25	32.4	2	1.9
	60	75.2	25	31.6	2	2.1
	60	66.0	25	23.6	2	2.5
	60	33.3	25	26.2	2	2.9
	60	45.2	25	23.9	2	2.0
	60	96.5	25	34.9	2	2.6
	60	89.8	25	30.2	2	1.8
	60	85.7	25	24.2	2	2.1
	60	98.5	25	31.0	2	1.9
	60	74.0	25	23.3	2	1.9
	60	78.0	25	25.1	2	2.1

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	53.3	25	25.0	2	2.1
	60	73.0	25	24.9	2	1.9
	60	37.6	25	25.9	2	2.0
	60	92.6	25	33.4	2	1.9
	60	99.2	25	29.7	2	2.0
	60	54.1	25	26.2	2	1.9
	60	36.9	25	27.7	2	2.3
	60	57.4	25	18.1	2	2.5
	60	74.2	25	36.9	2	2.1
	60	88.1	25	35.0	2	2.1
	60	88.8	25	28.8	2	1.6
	60	93.7	25	43.3	2	2.3
	60	89.3	25	36.8	2	2.0
	60	55.9	25	24.5	2	2.1
	60	60.7	25	28.4	2	2.1
	60	63.8	25	26.3	2	2.4
	60	79.9	25	26.9	2	2.3
	60	70.4	25	28.6	2	1.5
	60	91.2	25	34.2	2	2.3
	60	71.9	25	28.0	2	2.4
	60	57.1	25	24.2	2	2.4
	60	67.1	25	26.5	2	2.0
	60	65.3	25	25.8	2	2.1
	60	39.1	25	19.5	2	2.3
	60	72.2	25	21.3	2	2.1
	60	53.4	25	26.6	2	2.3
	60	63.4	25	29.4	2	1.3
	60	83.5	25	34.4	2	2.3
	60	83.1	25	30.5	2	1.3
	60	81.8	25	21.1	2	1.8
	60	41.6	25	21.5	2	2.4
	60	35.2	25	23.1	2	1.9
	60	72.6	25	30.2	2	1.9
	60	72.2	25	31.4	2	1.8
	60	55.4	25	20.6	2	1.6
	60	65.0	25	22.2	2	1.8
	60	59.0	25	27.4	2	2.0
	60	60.0	25	31.7	2	2.1
	60	86.1	25	36.4	2	2.3
	60	61.2	25	22.0	2	1.1
	60	80.3	25	32.5	2	2.6
	60	72.8	25	22.2	2	2.5
	60	82.4	25	31.2	2	2.3
	60	76.1	25	25.3	2	2.1
	60	70.3	25	23.0	2	1.8
	60	83.4	25	30.6	2	0.9
	60	67.9	25	29.4	2	1.4
	60	59.4	25	26.3	2	1.9

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	57.3	25	31.6	2	2.3
	60	51.5	25	24.0	2	0.9
	60	48.6	25	19.9	2	3.5
	60	63.0	25	30.2	2	2.1
	60	68.5	25	21.9	2	2.0
	60	77.4	25	25.5	2	2.1
	60	51.6	25	23.0	2	2.0
	60	49.8	25	21.5	2	2.3
	60	73.4	25	27.0	2	2.0
	60	67.2	25	26.2	2	1.5
	60	64.9	25	23.6	2	2.6
	60	59.1	25	26.2	2	2.0
	60	51.6	25	26.8	2	0.9
	60	75.3	25	24.3	2	1.1
	60	48.1	25	25.5	2	1.8
	60	88.1	25	22.9	2	2.0
	60	54.9	25	27.4	2	2.5
	60	52.2	25	24.8	2	2.3
	60	70.8	25	24.4	2	2.5
	60	57.6	25	19.0	2	3.0
	60	41.4	25	21.3	2	3.1
	60	46.6	25	24.2	2	2.4
	60	58.2	25	24.5	2	2.4
	60	54.9	25	27.4	2	2.5
	60	62.6	25	22.6	2	3.0
	60	46.9	25	27.4	2	2.5
	60	42.9	25	22.3	2	2.5
	-	-	25	22.5	2	4.2
	-	-	25	21.0	2	2.5
	60	89.8	25	34.0	2	2.0
	60	93.2	25	25.4	2	1.8
	-	-	25	21.2	2	0.9
	-	-	25	16.3	2	0.0
	-	-	25	21.2	2	0.0
	-	-	25	26.7	2	0.0
	-	-	25	25.4	2	2.1
	60	99.1	25	38.2	2	2.6
	-	-	25	26.1	2	0.0
	-	-	25	25.3	2	0.0
	-	-	25	25.3	2	0.0
	-	-	25	18.7	2	0.0
	-	-	25	22.4	2	1.6
	-	-	25	24.7	2	0.0
	-	-	25	33.4	2	0.0
	-	-	25	18.6	2	0.0
	-	-	25	24.7	2	0.0
	-	-	25	30.1	2	0.3
	-	-	25	23.8	2	0.0

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	82.7	25	30.8	2	1.7
	-	-	25	21.6	2	0.0
	-	-	25	27.9	2	0.0
	60	74.8	25	30.8	2	2.8
	60	60.7	25	26.8	2	5.3
	60	57.1	25	22.9	2	5.5
	60	47.8	25	30.4	2	2.9
	60	49.8	25	32.5	2	2.3
	-	-	25	28.4	2	2.1
	60	84.0	25	28.7	2	4.6
	60	44.7	25	29.6	2	2.3
	60	67.0	25	34.0	2	0.0
	60	55.1	25	25.7	2	1.9
	60	69.1	25	20.5	2	2.1
	60	57.3	25	27.8	2	2.4
	60	61.2	25	23.9	2	1.8
	60	54.1	25	34.7	2	2.5
	60	75.3	25	18.2	2	2.3
	60	62.1	25	19.7	2	2.4
	60	52.5	25	30.4	2	2.1
	60	61.9	25	20.3	2	2.0
	60	67.8	25	33.2	2	2.3
	60	45.2	25	27.3	2	2.8
	60	46.3	25	19.9	2	2.0
	60	71.1	25	18.8	2	2.1
	60	51.9	25	27.1	2	2.1
	60	45.5	25	20.8	2	2.1
	60	51.1	25	22.3	2	2.4
	60	57.9	25	26.1	2	2.0
	60	72.1	25	19.5	2	0.0
	60	54.9	25	22.7	2	0.0
	60	53.9	25	21.3	2	1.9
	60	58.9	25	24.9	2	2.1
	60	67.0	25	20.5	2	2.8
	60	59.0	25	23.0	2	2.0
	60	44.0	25	29.2	2	2.0
	60	48.8	25	31.6	2	2.3
	60	57.7	25	23.5	2	0.0
	60	45.2	25	23.7	2	2.6
	60	54.7	25	29.1	2	2.3
	60	54.5	25	31.9	2	2.3
	60	76.0	25	27.4	2	1.1
	60	52.7	25	20.3	2	0.0
	60	53.3	25	27.9	2	2.3
	60	80.1	25	17.0	2	1.9
	60	37.4	25	21.0	2	2.6
	60	69.0	25	24.4	2	2.3
	60	78.3	25	18.5	2	2.1

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	41.2	25	26.5	2	2.0
	60	59.0	25	23.0	2	0.0
	60	67.2	25	23.7	2	2.6
	60	51.8	25	22.1	2	2.0
	60	47.4	25	28.0	2	2.3
	60	95.6	25	21.8	2	7.3
	60	65.4	25	22.2	2	2.1
	60	89.5	25	28.4	2	2.5
	60	45.0	25	27.7	2	2.8
	60	40.2	25	24.1	2	0.0
	60	45.8	25	22.8	2	2.4
	60	71.3	25	27.5	2	2.0
	60	57.7	25	29.0	2	2.4
	60	60.4	25	28.6	2	0.0
	60	61.5	25	23.0	2	2.0
	60	74.1	25	25.1	2	0.0
	60	48.3	25	22.7	2	1.9
	60	51.0	25	22.9	2	2.3
	60	57.4	25	23.0	2	2.3
	60	59.9	25	24.9	2	2.5
	60	45.2	25	20.6	2	2.5
	60	66.3	25	21.1	2	1.9
	60	76.1	25	31.7	2	2.1
	60	50.1	25	23.3	2	2.0
	60	55.3	25	31.7	2	3.5
	60	78.6	25	23.2	2	0.0
	60	45.5	25	20.1	2	2.0
	60	55.8	25	22.0	2	3.4
	60	81.1	25	31.0	2	0.0
	60	50.3	25	26.0	2	2.0
	60	36.6	25	29.7	2	2.0
	60	73.8	25	29.5	2	1.8
	60	56.8	25	30.0	2	2.1
	60	51.5	25	31.8	2	2.5
	60	44.0	25	25.8	2	0.0
	60	67.3	25	24.2	2	2.5
	60	53.9	25	19.1	2	2.1
	60	51.2	25	22.8	2	2.0
	60	68.9	25	21.5	2	2.5
	60	54.0	25	21.5	2	2.0
	60	52.6	25	30.1	2	2.0
	60	51.3	25	23.5	2	1.8
	60	47.0	25	24.3	2	2.0
	60	52.8	25	30.6	2	2.1
	60	61.4	25	22.3	2	2.1
	60	70.3	25	22.2	2	2.0
	60	55.5	25	24.0	2	2.1
	60	55.6	25	18.4	2	2.0

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	69.6	25	26.0	2	2.5
	60	52.2	25	19.1	2	1.8
	60	78.0	25	23.5	2	2.4
	60	59.3	25	27.2	2	1.9
	60	86.1	25	27.0	2	2.5
	60	54.8	25	17.7	2	2.4
	60	63.4	25	25.1	2	2.3
	60	52.2	25	21.7	2	2.1
	60	55.2	25	19.1	2	2.3
	60	52.9	25	27.8	2	3.1
	60	77.4	25	28.1	2	2.1
	60	51.9	25	24.4	2	1.8
	60	51.2	25	23.0	2	2.3
	60	47.7	25	23.7	2	1.4
	60	50.9	25	28.5	2	2.3
	60	64.7	25	23.9	2	2.0
	60	67.2	25	20.2	2	2.3
	60	52.2	25	25.2	2	2.8
	60	43.1	25	24.4	2	1.8
	60	64.1	25	29.9	2	2.1
	60	59.1	25	16.3	2	2.0
	60	80.7	25	22.7	2	0.0
	60	50.5	25	18.8	2	2.5
	60	53.5	25	21.5	2	2.0
	60	56.0	25	24.2	2	1.9
	60	65.6	25	18.2	2	2.4
	60	52.0	25	23.1	2	2.0
	60	83.5	25	26.8	2	2.5
	60	43.9	25	19.6	2	1.9
	60	67.4	25	23.1	2	2.0
	60	51.4	25	23.5	2	2.0
	60	55.7	25	23.2	2	1.9
	60	55.6	25	21.8	2	2.4
	60	80.0	25	28.8	2	2.9
	60	56.1	25	22.3	2	2.6
	60	52.8	25	24.3	2	2.1
	60	44.2	25	23.7	2	2.1
	60	43.4	25	31.8	2	3.0
	60	55.7	25	17.6	2	2.3
	60	69.0	25	30.4	2	2.3
	60	53.8	25	25.8	2	2.3
	60	53.8	25	24.7	2	2.0
	60	36.9	25	21.1	2	1.3
	60	26.7	25	22.6	2	2.5
	60	28.8	25	18.4	2	2.3
	60	54.3	25	21.6	2	0.0
	60	43.6	25	40.2	2	1.4
	60	43.6	25	46.6	2	2.6
	60	98.7	25	46.3	2	3.5

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	71.4	25	29.5	2	2.3
	60	87.4	25	41.9	2	0.0
	60	72.2	25	37.6	2	1.5
	60	55.8	25	18.6	2	1.6
	60	65.0	25	19.3	2	1.9
	60	43.6	25	31.0	2	2.0
	60	60.4	25	30.0	2	2.0
	60	53.3	25	25.4	2	2.0
	60	50.9	25	28.5	2	2.0
	60	53.7	25	29.4	2	1.8
	60	58.7	25	33.7	2	1.8
	60	64.5	25	35.7	2	2.1
	60	42.5	25	21.7	2	1.9
	60	50.8	25	32.1	2	2.1
	60	65.9	25	31.7	2	2.1
	60	43.4	25	33.8	2	1.8
	60	84.6	25	23.6	2	2.2
	60	67.0	25	23.0	2	2.6
	60	84.7	25	30.2	2	2.4
	60	72.9	25	29.4	2	2.6
	60	73.9	25	29.6	2	2.0
	60	57.1	25	25.1	2	1.9
	60	88.3	25	27.8	2	2.0
	60	61.7	25	30.5	2	2.4
	60	64.0	25	26.5	2	1.8
	60	65.6	25	22.9	2	2.5
	60	97.3	25	21.5	2	2.5
	60	97.0	25	24.7	2	2.1
	60	68.3	25	24.5	2	2.1
	60	66.0	25	22.8	2	1.8
	60	55.8	25	34.6	2	2.3
	60	58.6	25	33.3	2	2.4
	60	35.1	25	24.5	2	0.0
	60	71.3	25	18.4	2	1.5
	60	66.8	25	24.3	2	3.3
	60	61.6	25	19.5	2	2.0
	60	66.0	25	34.7	2	2.0
	60	91.7	25	36.4	2	1.9
	60	62.8	25	26.7	2	3.0
	60	45.3	25	22.8	2	2.1
	60	68.7	25	27.1	2	3.4
	60	67.5	25	28.2	2	1.1
	60	57.5	25	28.8	2	2.0
	60	49.4	25	25.6	2	1.6
	60	57.1	25	28.7	2	0.9
	60	51.8	25	22.1	2	1.8
	60	82.2	25	23.4	2	1.6
	60	53.9	25	19.3	2	2.3

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	54.1	25	34.4	2	1.8
	60	33.8	25	20.7	2	1.8
	60	42.9	25	21.1	2	2.0
	60	69.0	25	37.9	2	2.0
	60	76.6	25	37.2	2	1.9
	60	53.6	25	18.8	2	2.0
	60	51.6	25	23.0	2	1.8
	60	56.1	25	32.4	2	2.5
	60	94.5	25	26.3	2	1.5
	60	68.0	25	31.5	2	3.0
	60	80.6	25	33.3	2	2.5
	60	54.4	25	25.7	2	1.6
	60	80.0	25	20.1	2	1.9
	60	75.2	25	28.1	2	2.0
	60	71.1	25	20.7	2	1.8
	60	70.8	25	23.6	2	1.8
	60	64.5	25	25.2	2	1.8
	60	55.8	25	23.9	2	1.8
	60	74.1	25	24.8	2	2.3
	60	51.8	25	24.5	2	2.1
	60	49.4	25	30.7	2	2.0
	60	51.2	25	23.3	2	2.1
	60	51.3	25	27.6	2	2.4
	60	82.8	25	31.0	2	1.9
	60	56.1	25	27.7	2	3.5
	60	70.4	25	31.1	2	3.0
	60	59.9	25	28.1	2	3.0
	60	66.1	25	26.8	2	2.3
	60	73.0	25	22.9	2	2.6
	60	96.1	25	33.7	2	2.4
	60	91.2	25	31.4	2	2.3
	60	83.7	25	35.9	2	1.9
	60	83.7	25	33.9	2	1.9
	60	42.0	25	26.8	2	1.9
	60	79.0	25	29.6	2	1.9
	60	88.8	25	29.3	2	2.0
	60	86.7	25	28.5	2	2.1
	60	82.6	25	28.5	2	2.3
	60	47.3	25	24.6	2	2.0
	60	61.2	25	28.5	2	1.8
	60	43.1	25	29.8	2	1.1
	60	58.6	25	34.2	2	2.0
	60	68.4	25	34.4	2	2.4
	60	52.4	25	23.7	2	1.5
	60	46.0	25	25.7	2	2.3
	60	68.3	25	28.2	2	2.3
	60	58.0	25	29.3	2	2.0
	60	98.0	25	36.2	2	2.5

ASPHALT TEST RESULTS 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	-	-	25	30.3	2	0.0
	60	88.9	25	26.3	2	1.9
	60	75.9	25	27.0	2	2.8
	60	55.3	25	25.6	2	2.1
	60	86.2	25	30.1	2	3.1
	60	54.6	25	26.7	2	4.0
	60	52.7	25	25.0	2	2.1
	60	79.7	25	24.8	2	2.2
	60	63.0	25	33.4	2	3.1
	60	95.4	25	22.0	2	1.1
	-	-	25	23.6	2	0.8
	-	-	25	24.8	2	2.0
	-	-	25	33.5	2	1.8
	-	-	25	34.7	2	1.4
	-	-	25	36.2	2	2.4
	-	-	25	38.0	2	1.9
	-	-	25	28.3	2	0.0
	-	-	25	42.6	2	2.3
	-	-	25	33.0	2	1.8
	-	-	25	29.6	2	2.0
	-	-	25	34.7	2	2.0
	-	-	25	34.4	2	2.1
	-	-	25	35.3	2	2.0
	-	-	25	29.9	2	2.1
	-	-	25	29.4	2	2.0
	-	-	25	24.5	2	2.1
	-	-	25	30.3	2	0.0
	60	44.7	25	30.9	2	2.9
	60	47.6	25	30.5	2	2.1
	60	66.3	25	22.5	2	2.0
	60	90.1	25	21.9	2	2.1
	60	68.8	25	21.1	2	2.3
	60	52.0	25	25.6	2	2.3
	60	53.7	25	27.0	2	2.0
	60	54.5	25	26.3	2	2.0
	60	34.4	25	24.5	2	1.5
	60	34.3	25	23.2	2	2.0
	60	66.4	25	26.8	2	1.8
	60	72.6	25	32.3	2	2.3
	60	82.0	25	28.6	2	2.0
	60	68.2	25	39.6	2	2.0
	60	55.1	25	31.7	2	2.0
	60	29.8	25	29.6	2	1.3
	60	63.2	25	19.3	2	0.9
	60	53.4	25	28.3	2	2.6
	60	58.4	25	32.7	2	0.1
	60	57.5	25	23.9	2	2.0

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
March	150	36.1	25	29.5	2	2.4
	60	85.3	25	23.3	2	1.0
	60	59.7	25	27.2	2	2.6
	60	101.0	25	23.7	2	2.6
	60	106.2	25	27.2	2	1.9
Milwaukee	-	-	23	23.6	2	1.8
	-	-	23	24.5	2	2.1
	60	185.7	23	25.3	2	2.7
	60	173.9	23	27.4	2	1.9
Platts-	60	51.0	23	12.8	2	2.4
burgh	60	36.0	23	22.6	2	2.7
	60	70.0	23	19.0	2	1.8
	60	42.0	23	17.1	2	2.1
	60	28.0	23	18.9	2	1.9
	60	40.0	23	24.6	2	2.1
	60	90.0	23	27.2	2	2.1
	75	67.0	23	21.0	2	1.8
	75	92.0	23	26.5	2	1.8
	60	60.0	23	16.1	2	1.8
	60	80.0	23	18.6	2	2.0
	60	48.0	25	16.2	2	2.6
	60	64.0	25	21.3	2	2.3
	60	32.0	25	23.6	2	1.7
	60	80.0	25	15.7	2	1.9
	60	58.0	25	19.4	2	2.1
	60	39.0	25	19.0	2	2.3
	60	50.0	25	23.1	2	1.8
	60	45.0	25	18.8	2	2.2
	60	52.0	23	21.2	2	2.1
	60	74.0	23	19.1	2	2.0
	60	79.0	23	17.5	2	1.8
	60	68.0	23	22.1	2	2.0
	60	33.9	23	18.2	2	1.8
	60	61.0	23	14.0	2	1.9
	60	69.0	23	19.0	2	2.2
	60	53.0	23	24.1	2	1.8
	60	154.0	23	23.2	2	1.6
	60	67.0	23	19.7	2	2.1
	60	49.0	23	22.3	2	1.6
	60	61.0	23	19.4	2	1.0
	60	83.0	23	24.9	2	2.0
	60	64.0	23	20.7	2	2.1
	60	125.0	23	18.5	2	1.3
	60	35.0	23	20.9	2	1.9
	60	68.0	23	19.0	2	2.3
	60	58.0	23	58.0	2	2.0
	60	45.0	23	25.0	2	2.2
	60	83.0	25	21.2	2	2.7

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Platts-	60	89.0	23	18.2	2	1.8
burgh	60	45.0	25	18.9	2	1.9
	60	59.0	23	19.7	2	2.0
	60	31.0	23	18.8	2	2.1
	60	48.0	25	21.5	2	1.9
	60	52.0	25	18.1	2	2.0
	60	28.0	23	35.2	2	1.8
	60	52.0	23	24.1	2	2.0
	60	94.0	25	21.6	2	0.4
	60	37.0	23	19.1	2	1.8
	60	73.0	23	18.1	2	2.0
	60	49.0	23	19.7	2	2.9
	60	97.0	23	21.9	2	2.1
	60	46.0	23	20.0	2	2.0
	60	86.0	23	23.4	2	0.6
	60	238.0	23	22.9	2	1.5
	60	75.0	23	19.7	2	1.8
	60	56.0	23	22.4	2	2.2
	60	29.0	23	20.2	2	2.1
	60	58.0	23	20.9	2	2.0
Andersen	120	89.0	25	20.6	2	2.0
	120	137.0	25	26.6	2	1.6
	120	32.0	25	21.7	2	0.2
	120	64.0	25	21.3	2	1.9
	120	126.0	25	24.9	2	2.0
	120	139.0	25	24.2	2	2.0
	120	89.0	25	17.9	-	-
	120	78.0	25	23.1	2	1.8
	120	114.0	25	21.3	2	2.5
	120	121.0	25	23.5	2	2.3
	120	94.0	25	32.2	2	2.4
	120	74.0	25	20.3	2	2.0
	120	124.0	25	23.1	2	2.2
	120	81.0	25	23.5	2	1.7
	120	120.0	25	22.2	2	2.0
	120	89.0	25	23.2	2	2.0
	120	73.0	25	17.5	2	2.3
	120	99.0	25	23.6	2	2.0
	120	103.0	25	18.8	2	2.0
	120	74.0	25	25.3	2	2.1
	120	98.0	25	18.1	2	2.0
	120	108.0	25	19.8	2	1.0
	120	92.0	25	21.7	2	2.0
	120	128.0	25	24.8	2	2.0
	120	92.0	25	19.4	2	1.8
	120	89.0	25	26.8	2	1.8
	120	81.0	25	23.5	2	1.9
	120	82.0	25	20.6	2	1.4

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Andersen	120	242.0	25	27.8	2	1.6
	120	89.0	25	32.5	2	1.8
	120	272.0	25	17.9	2	1.2
	120	150.0	25	16.8	2	1.8
	120	96.0	25	19.4	2	1.9
	120	109.0	25	22.6	2	2.2
	120	101.0	25	23.4	2	1.8
Blythe-	60	40.0	25	21.1	2	2.6
ville	60	58.0	25	18.1	2	2.5
Whiteman	-	-	25	15.8	2	1.9
	-	-	25	21.3	2	0.5
	-	-	25	21.9	2	2.8
	-	-	25	33.6	2	3.3
	-	-	25	38.8	2	2.5
Vanden-	60	43.0	25	21.3	2	3.2
burg	60	50.0	25	27.8	2	2.0
	60	80.0	25	24.3	2	2.4
	60	69.0	25	27.3	2	1.9
	60	108.0	25	21.6	2	1.5
Andersen	120	102.0	25	20.7	2	3.0
	120	87.0	25	19.4	2	2.4
	120	41.0	25	21.1	2	2.1
	120	43.0	25	26.5	2	2.5
	120	57.0	25	18.2	2	2.3
	120	72.0	25	23.8	2	2.2
	120	100.0	25	27.7	2	1.9
	120	112.0	25	18.9	2	2.1
	120	130.0	25	26.7	2	1.6
	120	99.0	25	20.7	2	2.7
	120	147.0	25	20.8	2	1.9
	120	90.0	25	20.5	2	2.5
	120	193.0	25	18.3	2	2.2
	120	131.0	25	18.4	2	2.1
	120	67.0	25	17.6	2	1.8
	120	128.0	25	21.7	2	2.0
	120	80.0	25	32.1	2	2.1
	120	75.0	25	17.2	2	3.1
	120	87.0	25	21.3	2	1.6
	120	89.0	25	23.1	2	2.1
	120	65.0	25	20.9	2	2.1
	120	86.0	25	21.8	2	2.0
	120	82.0	25	24.5	2	1.0
	120	98.0	25	16.9	2	2.3
	120	104.0	25	28.7	2	2.0
	120	117.0	25	25.2	2	2.2
	120	97.0	25	17.7	2	2.2
	120	108.0	25	21.3	2	1.2
	120	99.0	25	20.8	2	2.2

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Andersen	120	101.0	25	21.5	2	2.2
	120	129.0	25	18.9	2	2.2
	120	74.0	25	22.7	2	2.4
	120	55.0	25	16.4	2	2.7
	120	70.0	25	16.8	2	3.0
	120	67.0	25	23.6	2	1.7
	120	99.0	25	18.3	2	2.9
	120	109.0	25	21.5	2	2.1
	120	122.0	25	16.9	2	1.3
	120	111.0	25	17.2	2	2.0
	120	101.0	25	23.0	2	2.3
	120	177.0	25	17.4	2	2.2
	120	239.0	25	27.1	2	1.9
	120	190.0	25	17.8	2	1.8
	120	145.0	25	21.3	2	2.0
	120	98.0	25	28.4	2	1.8
	120	130.0	25	26.4	2	3.0
	120	47.0	25	23.7	2	2.1
	120	124.0	25	27.3	2	0.4
	120	118.0	25	24.0	2	1.8
	120	118.0	25	18.4	2	0.0
	120	138.0	25	21.5	2	0.7
	120	172.0	25	16.9	2	0.6
	120	50.0	25	16.5	2	1.0
	120	118.0	25	26.4	2	2.1
	120	118.0	25	26.4	2	2.1
	120	96.0	25	22.5	2	2.1
	120	219.0	25	21.5	2	2.1
	120	119.0	25	19.7	2	2.1
	120	155.0	25	24.7	2	2.4
	120	129.0	25	19.4	2	1.7
	120	192.0	25	25.3	2	2.1
	120	215.0	25	22.8	2	2.0
	120	48.0	25	28.7	2	3.1
	120	57.0	25	20.7	2	2.4
	120	55.0	25	19.2	2	2.2
	120	66.0	25	17.5	2	1.9
	120	85.0	25	19.6	2	2.5
	120	50.0	25	21.9	2	2.3
	120	90.0	25	22.6	2	2.5
	120	100.0	25	18.1	2	2.2
	120	38.0	25	21.3	2	2.5
	120	69.0	25	19.2	2	2.5
	120	89.0	25	28.4	2	2.5
	120	131.0	25	22.3	2	2.2
	120	105.0	25	15.7	2	2.3
	120	96.0	25	19.1	2	2.2
	120	138.0	25	26.8	2	2.6

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Andersen	120	126.0	25	27.7	2	2.4
	120	65.0	25	26.4	2	2.2
	120	109.0	25	23.1	2	2.7
	120	123.0	25	19.1	2	2.8
	120	108.0	25	21.3	2	2.3
	120	106.0	25	20.1	2	2.0
	120	71.0	25	22.9	2	2.1
	120	79.0	25	25.5	2	1.6
	120	83.0	25	19.7	2	2.0
	120	113.0	25	23.8	2	2.1
	120	139.0	25	24.4	2	2.4
	120	97.0	25	21.6	2	1.8
	120	149.0	25	15.7	2	2.3
	120	95.0	25	26.5	2	1.3
	120	129.0	25	29.1	2	2.1
	120	97.0	25	20.2	2	2.3
	120	99.0	25	21.1	2	2.1
	120	60.0	25	21.8	2	2.5
	120	78.0	25	26.6	2	1.9
	120	104.0	25	19.7	2	1.9
	120	189.0	25	20.2	2	2.1
	120	93.0	25	19.1	2	2.0
	120	143.0	25	18.9	2	2.1
	120	132.0	25	21.0	2	2.3
	120	102.0	25	17.5	2	2.6
	120	52.0	25	16.9	2	2.4
	120	153.6	25	26.8	2	2.4
	120	147.0	25	26.1	2	2.4
	120	165.0	25	22.6	2	2.0
	120	166.0	25	18.4	2	1.7
	120	179.0	25	20.3	2	1.8
	120	147.0	25	22.7	2	1.9
	120	178.0	25	22.0	2	1.4
	60	191.0	25	27.0	2	2.3
	60	252.0	25	27.5	2	2.1
	60	133.0	25	27.5	2	1.2
	60	137.0	25	28.5	2	1.6
	60	160.0	25	28.5	2	2.7
	60	192.0	25	27.5	2	1.6
	60	268.0	25	33.5	2	2.8
	60	146.0	25	31.6	2	2.0
	60	181.0	25	17.8	2	1.5
	60	159.0	25	21.8	2	3.0
	60	212.0	25	20.3	2	2.3
	60	190.0	25	16.0	2	2.6
	120	87.0	25	21.3	2	1.9
	120	137.0	25	31.3	2	2.0
	120	103.0	25	18.9	2	2.0

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Platts-burgh	60	100.0	23	31.1	2	1.8
	60	99.0	23	23.4	2	1.9
	60	68.0	23	19.7	2	1.5
	60	56.0	23	24.9	2	4.5
	60	44.0	23	23.8	2	1.8
	60	55.0	23	24.9	2	5.2
	60	49.0	23	18.0	2	1.3
	60	138.0	23	18.3	2	4.0
	75	36.0	23	22.3	2	1.6
	75	52.0	23	24.9	2	2.2
	75	43.0	23	26.6	2	2.5
	75	45.0	23	24.8	2	1.8
	60	64.0	23	18.4	2	2.1
	75	41.0	23	22.6	2	2.2
	75	59.0	23	24.2	2	1.8
	75	29.0	23	28.1	2	2.3
	60	82.0	23	24.5	2	2.1
	60	68.0	23	19.8	2	2.4
	60	100.0	23	24.8	2	1.2
	75	51.0	23	24.6	2	1.8
	60	84.0	23	18.4	2	1.8
Griffiss	60	24.0	23	20.8	2	3.7
	60	61.0	23	14.8	2	3.6
	60	67.4	23	26.6	2	0.1
	60	48.0	23	25.6	2	0.1
	60	53.0	23	27.0	2	0.0
	60	68.0	23	30.3	2	2.2
	60	56.0	23	40.0	2	2.2
	60	91.0	23	26.5	2	2.0
	60	103.0	23	25.4	2	2.2
	60	150.0	23	34.7	2	2.3
	60	155.0	23	25.8	2	2.7
	60	129.0	23	27.4	2	2.2
	60	17.0	23	25.0	2	1.6
	60	143.0	23	29.4	2	1.8
	60	31.0	23	27.9	2	1.6
	60	32.0	23	22.3	2	2.0
	60	79.0	23	27.3	2	2.1
	60	81.0	23	23.6	2	2.0
	60	53.0	23	20.0	2	3.0
	60	40.0	23	20.9	2	3.0
	60	32.0	23	22.6	2	2.8
	60	60.0	23	18.2	2	2.2
	60	36.0	23	20.0	2	3.0
	60	58.0	23	20.0	2	2.8
	60	97.0	23	15.1	2	4.8
	60	53.0	23	19.7	2	4.5
	60	57.0	23	20.6	2	0.5

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Griffiss	60	78.6	23	20.0	2	4.1
	60	64.0	23	20.4	2	1.2
	60	32.0	23	20.6	2	1.6
	60	37.0	23	23.9	2	1.9
	60	90.0	23	20.0	2	2.3
	60	106.0	23	20.3	2	1.3
	60	65.0	23	25.6	2	1.9
	60	33.0	23	21.8	2	3.0
	60	39.0	23	22.6	2	2.8
	60	41.0	23	20.1	2	2.1
	60	39.0	23	19.7	2	3.0
	60	100.0	23	18.0	2	0.0
	60	157.0	23	22.0	2	1.6
	60	74.0	23	18.8	2	2.0
	60	191.0	25	37.0	2	0.0
	60	89.0	25	34.0	2	2.9
	60	68.0	23	32.1	2	1.7
	60	42.0	23	32.9	2	2.0
Vanden-berg	60	163.0	25	26.6	2	3.0
	60	166.0	25	32.3	2	3.2
	60	112.0	25	21.3	2	3.2
	60	181.0	25	26.0	2	2.1
	60	155.0	25	37.0	2	0.5
	60	139.0	25	25.3	2	4.2
	60	93.0	25	26.8	2	4.3
	60	149.0	25	21.5	2	2.0
	60	111.0	25	31.0	2	3.6
	60	98.0	25	30.5	2	1.7
	60	106.0	25	26.0	2	1.4
	60	113.0	25	30.6	2	4.0
	60	109.0	25	27.3	2	1.0
	60	100.0	25	27.8	2	2.6
	60	73.0	25	30.0	2	3.0
	60	90.0	25	19.5	2	1.1
	60	59.0	25	31.2	2	1.9
	60	46.0	25	25.1	2	1.7
	60	61.0	25	19.3	2	2.0
Unknown	60	46.3	25	25.3	2	3.5
	60	67.6	25	31.5	2	3.1
	60	78.0	25	26.9	2	2.3
	60	47.6	25	24.9	2	3.6
	60	59.9	25	27.2	2	2.4
	60	68.5	25	23.1	2	1.8
	60	61.9	25	26.5	2	2.4
	60	55.3	25	27.0	2	2.3
	60	68.3	25	28.4	2	2.0
	60	36.8	25	22.4	2	2.1
	60	64.8	25	14.3	2	1.8

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	74.7	25	27.0	2	2.1
	60	58.2	25	11.3	2	2.1
	60	74.3	25	13.8	2	2.4
	60	60.7	25	18.6	2	2.1
	60	52.4	25	13.2	2	2.1
	60	89.2	25	13.6	2	0.0
	60	58.4	25	16.3	2	2.0
	60	59.9	25	11.8	2	2.6
	60	76.7	25	22.7	2	2.0
	60	81.7	25	16.2	2	2.6
	60	71.2	25	19.1	2	2.1
	60	69.9	25	16.7	2	1.6
	60	60.3	25	17.8	2	2.3
	60	60.5	25	23.3	2	2.0
	60	84.5	25	30.1	2	2.4
	60	68.8	25	34.2	2	2.9
	60	60.9	25	22.4	2	1.6
	60	87.9	25	24.7	2	2.4
	60	56.7	25	32.2	2	1.5
	60	71.8	25	35.2	2	1.9
	60	60.8	25	42.4	2	0.0
	60	57.9	25	32.0	2	1.3
	60	56.5	25	29.2	2	2.0
	60	60.0	25	25.6	2	1.9
	60	58.9	25	34.2	2	2.0
	60	54.7	25	27.4	2	1.4
	60	67.4	25	32.8	2	1.6
	60	60.6	25	33.1	2	2.0
	-	-	25	32.1	2	2.5
	-	-	25	27.6	2	2.5
	60	24.2	25	22.0	2	2.6
	60	57.1	25	24.9	2	2.3
	60	52.4	25	21.8	2	2.0
	60	57.0	25	23.7	2	1.8
	60	55.7	25	27.8	2	1.6
	60	49.2	25	16.9	2	1.8
	60	55.1	25	30.4	2	2.0
	60	56.2	25	28.5	2	2.1
	60	54.7	25	26.2	2	2.3
	60	91.1	25	24.0	2	2.1
	60	53.8	25	27.8	2	1.5
	60	70.7	25	26.4	2	2.0
	60	70.8	25	27.2	2	1.8
	60	60.2	25	23.5	2	1.9
	60	84.7	25	22.0	2	1.8
	60	73.3	25	29.4	2	2.0
	60	67.5	25	33.5	2	2.3
	-	-	25	35.8	2	2.3

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	85.7	25	20.9	2	1.9
	-	-	25	29.9	2	2.1
	-	-	25	29.8	2	1.5
	-	-	25	30.3	2	2.3
	-	-	25	35.4	2	2.0
	60	47.6	25	21.6	2	1.6
	60	77.8	25	21.9	2	2.4
	60	53.7	25	25.5	2	1.8
	60	94.6	25	29.1	2	2.1
	60	62.9	25	20.9	2	2.0
	60	70.3	25	25.3	2	1.4
	60	70.9	25	24.4	2	1.9
	60	58.2	25	24.8	2	2.1
	60	51.7	25	23.9	2	1.9
	60	62.8	25	23.2	2	1.9
	60	65.9	25	24.5	2	1.9
	60	90.8	25	29.5	2	2.0
	60	84.9	25	25.4	2	0.0
	60	61.6	25	25.1	2	1.9
	-	-	25	32.5	2	1.3
	60	67.4	25	24.8	2	2.0
	60	84.5	25	33.8	2	1.5
	60	86.3	25	26.8	2	2.5
	60	61.2	25	20.6	2	2.0
	60	71.1	25	26.8	2	2.3
	60	62.5	25	18.6	2	1.5
	60	92.4	25	26.8	2	1.8
	60	67.5	25	32.3	2	1.8
	60	40.8	25	25.5	2	1.9
	60	81.5	25	30.5	2	2.0
	60	62.5	25	29.5	2	2.4
	60	52.0	25	32.6	2	2.1
	60	51.5	25	24.7	2	2.1
	60	65.3	25	36.8	2	2.4
	60	97.9	25	42.9	2	1.5
	60	75.8	25	28.5	2	1.6
	60	58.2	25	27.3	2	2.0
	60	31.0	25	32.8	2	2.1
	60	35.6	25	31.4	2	2.6
	60	62.7	25	19.6	2	1.6
	60	43.6	25	18.9	2	1.3
	60	61.6	25	24.9	2	1.6
	60	68.7	25	22.0	2	3.9
	-	-	25	42.0	2	1.8
	-	-	25	21.3	2	1.6
	-	-	25	17.0	2	3.5
	60	42.3	25	28.0	2	2.1
	60	50.0	25	21.8	2	2.5

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	ACTUAL	INTERPLY(lbs/sq) REQUIRED	ACTUAL	HEADLAP(inch) REQUIRED	ACTUAL
Unknown	60	50.7	25	28.8	2	3.5
	60	36.1	25	33.0	2	2.6
	60	40.0	25	24.0	2	2.1
	60	43.6	25	30.4	2	2.0
	60	29.1	25	24.9	2	2.0
	60	46.2	25	22.7	2	0.0
	60	82.5	25	22.1	2	0.0
	60	51.6	25	47.6	2	1.9
	60	66.9	25	26.4	2	1.9
	60	65.0	25	33.6	2	0.0
	60	42.5	25	32.5	2	2.4
	60	45.1	25	28.6	2	2.6
	60	35.1	25	31.2	2	2.4
	60	44.9	25	26.9	2	3.8
	60	56.1	25	31.6	2	3.3
	60	57.1	25	30.0	2	3.3
	60	51.7	25	29.6	2	3.3
	60	82.0	25	35.8	2	2.3
	60	62.8	25	29.4	2	3.5
	60	81.6	25	27.0	2	1.8
	60	68.9	25	33.7	2	2.9
	60	66.4	25	34.4	2	2.0
	60	69.5	25	35.9	2	1.9
	60	73.0	25	29.9	2	1.9
	60	51.7	25	25.2	2	3.1
	60	74.0	25	36.9	2	2.5
	60	77.3	25	27.9	2	1.6
	60	84.1	25	34.0	2	3.2
	60	45.4	25	23.5	2	4.1
	60	45.4	25	23.5	2	0.0
	60	48.5	25	21.7	2	2.6
	60	56.2	25	25.9	2	2.8
	60	58.6	25	21.7	2	1.8
	60	39.5	25	19.7	2	2.0
	60	35.3	25	17.4	2	3.4
	60	70.4	25	28.7	2	3.3
	60	48.4	25	24.5	2	2.0
	60	55.5	25	22.5	2	2.4
	60	51.1	25	24.3	2	1.9
	60	76.5	25	22.6	2	3.8
	60	25.1	25	20.0	2	3.4
	60	53.9	25	21.3	2	2.0
	60	56.0	25	22.5	2	1.8
	60	53.1	25	21.4	2	2.0
	60	65.7	25	28.8	2	2.1
	60	52.0	25	38.7	2	1.3
	60	87.5	25	25.1	2	0.0
	60	62.8	25	33.9	2	0.5

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	-	-	25	21.2	2	3.6
	60	86.5	25	29.3	2	2.8
	60	27.1	25	22.3	2	3.3
	60	30.2	25	21.0	2	0.0
	60	54.3	25	19.0	2	2.9
	60	40.0	25	20.4	2	1.3
	60	51.1	25	26.5	2	0.0
	60	74.8	25	23.3	2	1.8
	60	39.5	25	22.8	2	0.0
	60	45.5	25	19.9	2	1.8
	60	15.7	25	23.2	2	0.4
	60	75.6	25	20.1	2	2.1
	60	36.6	25	19.8	2	2.6
	60	84.8	25	25.2	2	2.4
	60	36.6	25	25.5	2	2.1
	60	64.5	25	19.5	2	1.5
	60	47.0	25	24.6	2	2.9
	60	33.9	25	23.2	2	0.8
	60	73.0	25	19.5	2	1.0
	60	83.6	25	21.8	2	0.3
	60	63.1	25	23.0	2	1.6
	60	57.3	25	26.4	2	1.5
	60	81.5	25	24.8	2	2.1
	60	82.2	25	25.5	2	4.9
	60	67.6	25	22.7	2	2.1
	60	65.8	25	24.8	2	1.3
	60	40.1	25	21.4	2	1.3
	60	65.4	25	21.0	2	2.4
	60	62.0	25	21.9	2	4.9
	60	78.4	25	23.6	2	1.9
	60	48.1	25	19.5	2	2.0
	60	46.2	25	21.0	2	2.1
	-	-	25	18.4	2	2.5
	-	-	25	45.0	2	2.3
	-	-	25	19.7	2	1.8
	-	-	25	20.0	2	1.6
	-	-	25	22.9	2	2.1
	-	-	25	19.4	2	2.0
	60	83.8	25	27.4	2	0.0
	60	74.3	25	29.2	2	1.8
	60	48.5	25	31.1	2	0.0
	60	64.2	25	25.4	2	2.0
	-	-	25	16.9	2	1.6
	-	-	25	21.0	2	1.8
	-	-	25	20.7	2	3.5
	60	43.2	25	20.8	2	3.0
	60	98.7	25	18.7	2	2.3
	60	56.3	25	33.3	2	2.3

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	71.1	25	21.0	2	2.6
	60	28.5	25	21.0	2	1.5
	60	41.8	25	29.5	2	1.5
	60	69.5	25	29.9	2	1.6
	60	99.2	25	29.7	2	1.9
	60	59.7	25	24.5	2	1.1
	60	59.7	25	27.6	2	2.0
	60	61.6	25	27.4	2	1.6
	60	69.1	25	24.3	2	1.8
	60	60.8	25	26.5	2	2.1
	60	56.3	25	27.7	2	1.8
	60	59.8	25	28.7	2	1.9
	60	43.5	25	28.4	2	1.9
	60	40.6	25	26.7	2	2.0
	60	53.9	25	30.5	2	2.0
	60	36.7	25	24.3	2	1.5
	60	63.4	25	26.2	2	2.1
	60	62.8	25	27.3	2	1.8
	60	69.6	25	24.5	2	1.0
	60	49.7	25	34.2	2	3.5
	60	64.8	25	32.7	2	2.4
	60	54.2	25	24.1	2	2.0
	60	91.8	25	30.7	2	2.1
	60	94.0	25	36.2	2	1.6
	60	66.6	25	27.3	2	2.0
	60	53.3	25	25.9	2	0.9
	60	58.1	25	33.3	2	1.9
	60	68.8	25	23.9	2	2.1
	60	73.6	25	23.2	2	3.1
	60	68.7	25	19.4	2	2.6
	60	61.2	25	28.2	2	1.5
	60	99.2	25	29.3	2	1.8
	60	64.4	25	30.3	2	3.9
	-	-	25	21.5	2	3.8
	-	-	25	24.4	2	2.0
	60	69.1	25	35.0	2	2.1
	60	67.0	25	25.2	2	1.8
	60	65.8	25	25.5	2	1.9
	60	69.3	25	31.0	2	1.9
	60	69.1	25	35.0	2	2.1
	60	74.7	25	26.2	2	1.0
	60	49.2	25	28.6	2	1.6
	60	52.6	25	31.5	2	3.0
	60	99.7	25	41.8	2	1.9
	60	67.6	25	24.7	2	1.5
	60	76.5	25	27.3	2	2.0
	60	52.4	25	29.5	2	1.9
	60	66.6	25	28.1	2	3.4

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	71.1	25	21.0	2	2.6
	60	65.7	25	23.4	2	0.0
	60	63.4	25	31.2	2	3.5
	60	51.2	25	23.7	2	1.6
	60	32.6	25	32.7	2	3.5
	60	63.4	25	32.1	2	3.8
	60	64.7	25	23.6	2	2.5
	60	58.0	25	22.7	2	5.4
	60	57.2	25	36.3	2	2.1
	60	57.0	25	21.3	2	5.5
	60	99.0	25	33.9	2	3.1
	60	53.7	25	34.6	2	1.4
	60	42.3	25	26.0	2	3.3
	60	61.2	25	28.5	2	3.0
	60	65.5	25	33.2	2	2.6
	60	64.5	25	32.0	2	1.6
	60	41.8	25	29.2	2	1.9
	60	64.3	25	24.5	2	2.3
	60	63.6	25	22.6	2	2.1
	60	85.2	25	27.4	2	2.0
	60	54.1	25	28.6	2	2.4
	60	94.0	25	29.0	2	2.4
	60	77.3	25	31.6	2	5.5
	60	74.1	25	27.6	2	1.9
	60	66.6	25	21.6	2	2.1
	60	57.1	25	22.6	2	1.5
	60	61.2	25	32.7	2	1.3
	60	51.4	25	29.4	2	2.0
	60	92.7	25	27.6	2	1.3
	60	58.3	25	30.1	2	1.9
	60	65.7	25	30.4	2	1.8
	60	64.8	25	37.9	2	1.4
	60	69.4	25	36.9	2	1.1
	60	60.4	25	30.2	2	2.5
	60	59.3	25	31.9	2	2.5
	60	64.8	25	24.9	2	1.9
	60	61.8	25	25.0	2	2.6
	60	57.5	25	21.9	2	4.8
	60	78.5	25	26.2	2	1.8
	60	45.4	25	27.1	2	1.6
	60	94.4	25	29.2	2	1.6
	60	99.2	25	31.9	2	1.2
	60	95.9	25	25.0	2	1.9
	60	55.1	25	28.9	2	2.4
	60	61.1	25	30.3	2	1.8
	60	53.4	25	24.2	2	1.1
	60	61.9	25	27.9	2	1.8
	60	59.5	25	33.4	2	1.4

ASPHALT TEST RESULTS 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) REQUIRED	HEADLAP(inch) ACTUAL
Unknown	60	91.5	25	22.6	2	2.3
	60	55.5	25	28.0	2	2.5
	60	74.1	25	21.1	2	2.3
	60	86.9	25	30.3	2	2.3
	60	85.5	25	27.5	2	1.9
	60	88.4	25	17.9	2	2.6
	60	86.0	25	18.2	2	2.0
	60	81.6	25	26.2	2	2.1
	60	61.6	25	24.5	2	1.1
	60	68.5	25	25.2	2	2.6
	60	96.4	25	30.2	2	1.6
	60	66.3	25	28.7	2	3.8
	60	79.7	25	28.9	2	3.8
	60	61.7	25	24.1	2	1.9
	60	67.9	25	23.5	2	3.0
	60	51.7	25	23.8	2	3.4
	60	71.7	25	30.0	2	1.3
	60	69.4	25	31.2	2	3.5
	60	59.7	25	19.0	2	6.5
	60	51.7	25	27.5	2	3.3
	60	73.7	25	22.7	2	2.1
	-	-	25	20.9	2	2.5
	-	-	25	30.7	2	1.3
	-	-	25	34.6	2	0.0
	-	-	25	28.2	2	0.0
	-	-	25	16.0	2	2.0
	60	70.9	25	28.4	2	2.0
	60	56.4	25	36.9	2	2.3
	60	44.3	25	30.1	2	2.1
	60	40.8	25	34.8	2	2.1
	60	57.4	25	22.6	2	2.0
	60	70.8	25	27.2	2	2.0
	60	81.6	25	30.5	2	2.3
	60	75.8	25	25.7	2	2.8
	60	52.1	25	30.9	2	1.8
	60	50.3	25	29.2	2	2.4
	60	71.8	25	26.9	2	1.9
	60	81.6	25	34.1	2	2.5
	60	67.1	25	26.4	2	2.0
	60	58.1	25	30.7	2	2.3

1982

Base	AGGREGATE(Asphalt Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
Blyth-ville	700	734.8	639.8	60	94.4
	400	228.9	195.0	60	85.2
	400	255.9	197.4	60	77.1
	400	266.0	254.9	60	95.8
	400	287.9	193.1	60	67.0
	400	329.7	223.0	60	67.6
	400	198.8	153.8	60	77.4
	400	285.3	148.5	60	52.1
	400	278.0	162.1	60	58.3
	400	233.1	156.6	60	67.2
	400	164.8	60.8	60	36.8
	800	767.6	751.3	60	97.9
	800	800.0	798.8	60	98.7
	800	768.5	765.0	60	99.5
March	300	265.7	265.7	66	100.0
	300	496.7	496.7	66	100.0
	300	296.5	284.4	66	95.9
	300	407.8	303.8	66	74.5
	300	262.3	257.0	60	98.0
	300	279.9	263.4	60	94.1
	300	356.0	343.2	60	96.4
	300	236.7	197.1	60	83.3
	400	284.6	284.6	60	100.0
	525	333.0	309.6	100	93.0
	525	462.1	462.1	100	100.0
	345	458.4	458.4	100	100.0
	345	437.1	437.1	100	100.0
	483	447.8	447.8	100	100.0
	345	423.5	423.5	100	100.0
	345	201.5	201.5	100	100.0
	345	346.0	346.0	100	100.0
	345	353.2	353.2	100	100.0
	345	172.6	-	100	-
	345	240.1	-	100	-
	345	297.2	297.2	100	100.0
	345	212.1	-	100	-
	345	263.0	-	100	-
	345	285.8	-	100	-
	345	226.0	-	100	-
	345	319.7	319.7	100	100.0
	483	348.9	348.9	100	100.0
	483	391.3	391.3	100	100.0
Beale	400	237.9	147.4	50	62.0
	400	267.0	186.1	50	69.7
	400	205.1	157.9	50	77.0
	400	207.0	151.8	50	73.3
	400	222.7	162.8	50	73.1
	400	255.9	181.4	50	70.9
	400	220.1	127.9	50	58.1

1982

Base	AGGREGATE (Asphalt Bitumen) Quantity (lbs/sq) Required	Actual	Embedment Actual (lbs/sq)	Embedment (%) Required	Actual
Loring	400	472.5	250.5	50	53.0
	400	499.7	284.0	50	56.8
	400	474.4	230.5	50	48.6
	400	603.2	387.5	50	64.2
	300	305.8	-	60	70.8
	300	326.7	-	60	68.0
	300	330.3	-	60	77.9
	300	320.7	223.6	60	69.7

1983

Base	AGGREGATE(Asphalt Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
March	345	313.9	-	100	100.0
	345	347.1	-	100	100.0
	345	325.1	-	100	100.0
	483	497.4	497.4	100	100.0
	483	296.5	296.5	100	100.0
	345	471.5	-	100	100.0
	345	402.8	-	100	100.0
	483	444.7	444.7	100	100.0
	483	581.2	487.7	100	83.9
	483	423.4	423.4	100	100.0
	345	420.2	-	100	100.0
	345	350.2	-	100	100.0
	483	533.7	365.3	100	68.4
	483	284.5	196.8	100	69.2
	483	337.0	295.9	100	87.8
	483	329.4	269.7	100	81.8
	483	339.1	125.7	100	37.0
	483	250.5	250.5	100	100.0
	483	304.9	304.9	100	100.0
	483	747.7	547.7	100	73.3
	483	587.3	299.1	100	50.9
	483	774.9	498.9	100	64.4
	483	226.7	181.7	100	80.0
	483	827.3	407.5	100	49.3
	483	722.7	227.9	100	31.5
	483	705.8	433.3	100	61.4
	483	588.3	398.0	100	67.7
	483	746.5	540.3	100	72.4
	483	415.8	270.3	100	65.6
	483	620.2	358.6	100	57.8
	483	492.8	274.1	100	55.6
	483	514.5	359.6	100	69.9
	483	509.5	244.8	100	48.0
	483	657.5	329.0	100	50.0
	483	655.5	405.1	100	61.8
	483	406.4	223.9	100	55.0
	483	548.3	200.0	100	36.5
	483	549.7	362.6	100	66.0
	400	259.3	125 0	60	48.2
	400	494.7	316.9	60	64.1
	400	636.0	200.8	60	31.5
	400	691.0	275.0	60	39.8
	400	654.5	242.5	60	37.1
	400	565.6	286.3	60	50.0
	400	698.0	219.0	60	31.4
	400	636.6	295.7	60	46.5
	400	469.1	327.5	60	69.8

1983

Base	AGGREGATE(Asphalt Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
Pease	400	377.1	298.9	60	79.0
	400	438.5	216.4	60	49.4
	400	271.3	234.9	60	86.6
	400	196.6	196.6	60	100.0
	400	433.2	158.4	60	36.6
	400	461.6	309.3	60	67.0
	400	701.2	377.0	60	53.9
	400	463.4	149.4	60	32.2
K.I.	400	474.0	216.1	60	45.6
Sawyer	400	360.4	328.8	60	91.2
	400	362.7	322.4	60	88.9
	400	355.9	298.8	60	84.0
	400	343.1	284.4	60	82.9
	400	341.6	306.6	60	89.8
	400	300.6	196.6	60	65.4
	400	294.5	276.8	60	94.0
	400	327.5	316.1	60	96.5
	400	435.6	334.3	60	76.7
	400	435.0	246.9	60	56.8
	400	368.8	294.3	60	79.8
	400	407.7	249.5	60	61.2
	400	392.6	257.0	60	65.5
	400	441.3	323.9	60	73.3
	400	371.6	292.0	60	78.6
	400	182.5	182.5	60	100.0
	400	369.1	198.3	60	53.7
	400	346.5	157.7	60	45.5
	400	379.9	268.6	60	70.9
	400	419.9	253.2	60	60.3
	400	373.9	242.4	60	64.8
	400	409.0	253.8	60	62.1
	400	386.3	199.2	60	51.6
	400	410.3	125.7	60	30.6
	400	440.5	195.4	60	48.8
	400	411.3	166.6	60	40.5
	400	442.2	245.1	60	55.4
	400	400.3	263.5	60	65.8
	400	401.4	274.8	60	68.5
	400	412.2	254.9	60	61.8
	400	394.3	312.9	60	79.4
	400	381.1	265.2	60	69.6
	400	396.5	213.7	60	53.9
	400	406.1	232.0	60	57.1
	400	383.0	293.4	60	76.6
	400	366.3	269.2	60	73.5
	400	301.7	241.6	60	63.3
	400	385.1	225.2	60	58.4

1983

Base	AGGREGATE(Asphalt Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
K.I.	400	435.6	340.3	60	78.1
Sawyer	400	376.9	292.4	60	77.6
	400	279.1	201.1	60	72.1
	400	405.8	229.4	60	56.5
	400	424.4	312.2	60	74.0
	400	407.7	325.0	60	80.0
	400	413.3	302.0	60	73.0
	400	384.6	256.2	60	66.6
	400	377.2	244.8	60	64.9
	400	331.6	274.0	60	82.6
Seymour	400	522.4	323.1	60	62.0
Johnson	400	367.5	-	60	62.8
	400	439.6	-	60	30.7
	400	385.5	-	60	49.9
	400	397.5	-	60	84.8
	400	503.7	-	60	89.3
	400	470.3	-	60	89.9
Vanden-	400	546.3	194.0	60	35.5
berg	400	468.4	197.9	60	42.3
	400	517.4	200.6	60	38.8
	400	514.5	297.1	60	57.7
	400	521.0	261.5	60	50.2
	400	400.3	209.9	60	52.4
	400	335.9	189.9	60	56.4
Little	400	534.0	-	60	69.0
Rock	400	479.0	-	60	73.0
	400	435.0	-	60	82.0
	400	946.0	-	60	30.0
	400	400.0	-	60	74.0
	400	395.0	-	60	72.0
	400	389.0	-	60	81.0
	400	263.0	-	60	81.0
	400	257.0	-	60	93.0
	400	229.0	-	60	-
	400	362.0	-	60	90.0
	400	447.0	-	60	89.0
	400	342.0	-	60	46.0
	400	506.0	-	60	93.0

1984

Base	AGGREGATE(Asphalt Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
March	400	981.2	346.4	60	35.3
	400	328.8	268.0	60	81.5
	400	394.3	319.6	60	81.1
	400	542.9	378.0	60	69.6
	400	488.4	395.5	60	81.0
	400	696.3	648.6	60	93.1
	400	684.2	623.9	60	91.2
	400	551.4	481.6	60	87.3
	400	480.7	391.9	60	81.5
	400	521.5	499.3	60	95.7
	400	396.6	334.4	60	84.3
	400	430.8	385.4	60	89.5
	400	377.6	335.9	60	89.0
	400	401.6	366.2	60	91.2
	400	336.4	269.0	60	83.0
	400	332.1	290.5	60	87.5
Dover	700	600.0	110.5	60	42.5
	700	471.2	204.8	60	43.5
	700	491.8	263.6	60	53.6
	700	593.1	364.7	60	61.5
	700	633.8	312.7	60	49.3
	700	521.2	194.5	60	37.3
	700	619.4	340.8	60	55.0
	700	441.1	197.5	60	44.8
	700	468.8	267.3	60	57.0
	700	471.5	303.4	60	64.3
	700	413.9	242.6	60	58.6
	700	479.6	305.2	60	63.6
	525	514.2	152.6	60	30.0
	300	399.5	164.8	60	41.2
	300	398.7	208.4	60	50.0
	300	428.2	199.8	60	46.7
	300	401.0	210.8	60	52.6
	700	927.5	715.0	60	77.1
	300	274.5	115.9	60	42.2
	300	438.1	152.6	60	34.8
	300	288.8	155.6	60	53.9
	300	223.1	223.1	60	100.0
	300	334.9	162.4	60	48.5
	300	342.1	242.9	60	71.0
	300	286.9	286.9	60	100.0
Loring	700	901.0	-	60	100.0
	700	837.0	-	60	100.0
	700	912.0	-	60	100.0
	700	589.0	-	60	100.0
	400	377.0	-	60	40.0
	400	449.0	-	60	53.0

1984

	AGGREGATE(Asphalt Bitumen)				
	Quantity(lbs/sq)		Embedment	Embedment(%)	
Base	Required	Actual	Actual(lbs/sq)	Required	Actual
Loring	700	689.0	-	60	100.0
	700	958.0	-	60	100.0
	700	1032.0	-	60	95.0
	700	924.0	-	60	100.0
McConnell	400	413.0	172.0	60	41.6
	400	451.0	217.0	60	48.1
	400	415.0	206.0	60	49.6
	400	737.0	640.0	60	86.8
	400	534.0	424.0	60	79.4
	400	544.0	369.0	60	67.8
	400	406.0	246.0	60	60.6
Andersen	400	310.0	-	60	100.0
	400	1042.0	-	60	100.0
	400	541.0	-	60	90.0
	400	1028.0	-	60	100.0
	400	455.0	-	60	100.0
	400	951.0	-	60	93.0
	400	489.0	-	60	97.0
	400	576.0	-	60	100.0
	400	433.0	-	60	100.0
	400	336.0	-	60	100.0
	400	263.0	-	60	100.0
	400	170.0	-	60	100.0
	400	192.0	-	60	100.0
	400	457.0	-	60	100.0
	400	724.0	-	60	100.0
	400	304.0	-	60	100.0
	400	496.0	-	60	100.0
	400	369.0	-	60	100.0
	400	598.0	-	60	86.0
	400	530.0	-	60	74.0
	400	456.0	-	60	83.0
	400	392.0	-	60	73.0
	400	531.0	-	60	100.0
	400	404.0	-	60	100.0
	400	513.0	-	60	100.0
	400	475.0	-	60	100.0
	400	520.0	-	60	100.0
Griffiss	400	391.0	-	60	100.0
	400	259.0	-	60	100.0
	400	383.0	-	60	100.0
Vanden-berg	400	251.0	-	60	63.0
	400	313.0	-	60	63.0
	400	425.0	-	60	34.0
	400	314.0	-	60	54.0
	400	374.0	-	60	67.0

1985

Base	AGGREGATE(Asphalt Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
March	400	452.4	241.8	60	43.8
	400	506.2	152.9	60	30.2
	400	614.2	345.4	60	56.2
	400	601.0	240.5	60	40.0
Milwaukee	400	661.2	525.6	60	79.5
	400	704.3	652.1	60	92.6
Platts-	400	366.0	311.0	60	85.0
burgh	400	342.0	232.0	60	67.8
	400	436.0	347.0	60	79.6
	400	628.0	272.0	60	43.3
	400	328.0	204.0	60	62.2
	400	427.0	183.0	60	42.9
	400	587.0	419.0	60	71.4
	400	512.0	397.0	60	77.5
	400	599.0	507.0	60	84.6
	400	741.0	285.0	60	38.5
	400	686.0	447.0	60	65.2
	400	434.0	211.0	60	48.6
	400	581.0	395.0	60	68.0
	400	548.0	445.0	60	81.2
	400	336.0	211.0	60	62.8
	400	585.0	431.0	60	73.7
	400	512.0	234.0	60	45.7
	400	543.0	303.0	60	55.8
	400	448.0	344.0	60	76.8
	400	550.0	420.0	60	76.4
	400	509.0	317.0	60	62.3
	400	417.0	243.0	60	58.3
	400	456.0	319.0	60	70.0
	400	570.0	411.0	60	72.1
	400	374.0	264.0	60	70.6
	400	688.0	513.0	60	74.6
	400	425.0	363.0	60	85.4
	400	387.0	240.0	60	62.0
	400	481.0	376.0	60	78.2
	400	501.0	416.0	60	83.0
	400	545.0	323.0	60	59.3
	400	501.0	436.0	60	87.0
	400	342.0	201.0	60	58.8
	400	433.0	266.0	60	61.4
	400	428.0	317.0	60	74.1
	400	496.0	306.0	60	61.7
	400	512.0	478.0	60	93.4
	400	581.0	347.0	60	59.7
	400	360.0	222.0	60	61.7
	400	574.0	371.0	60	64.6
	400	487.0	195.0	60	40.0

1985

Base	Quantity (lbs/sq) Required	Quantity (lbs/sq) Actual	Embedment Actual (lbs/sq)	Embedment (%) Required	Embedment (%) Actual
	AGGREGATE (Asphalt Bitumen)				
Platts-burgh	400	456.0	182.0	60	39.9
	400	393.0	170.0	60	43.3
	400	352.0	274.0	60	77.8
	400	436.0	300.[illegible]	60	68.8
	400	589.0	456.0	60	77.4
	400	509.0	338.0	60	66.4
	400	572.0	300.0	60	52.4
	400	535.0	296.0	60	55.3
	400	642.0	519.0	60	80.8
	400	443.0	269.0	60	60.7
	400	454.0	324.0	60	71.4
	400	744.0	550.0	60	73.9
	400	535.0	388.0	60	72.5
	400	489.0	357.0	60	73.0
	400	348.0	221.0	60	63.5
	400	393.0	283.0	60	72.0
Andersen	400	416.0	400.0	100	96.2
	400	664.0	613.0	100	92.3
	400	211.0	150.0	100	71.1
	400	326.0	269.0	100	82.5
	400	480.0	432.0	100	90.0
	400	436.0	356.0	100	81.7
	400	468.0	420.0	100	89.7
	400	497.0	453.0	100	91.1
	400	502.0	437.0	100	87.1
	400	451.0	451.0	100	100.0
	400	557.0	445.0	100	79.9
	400	542.0	465.0	100	85.8
	400	515.0	436.0	100	84.7
	400	342.0	253.0	100	74.0
	400	395.0	350.0	100	88.6
	400	440.0	338.0	100	76.8
	400	320.0	213.0	100	66.6
	400	280.0	256.0	100	91.4
	400	420.0	336.0	100	80.0
	400	329.0	276.0	100	83.9
	400	355.0	333.0	100	93.8
	400	430.0	354.0	100	82.3
	400	531.0	491.0	100	92.5
	400	574.0	503.0	100	87.6
	400	468.0	400.0	100	85.5
	400	438.0	295.0	100	67.4
	400	501.0	288.0	100	57.5
	400	448.0	384.0	100	85.7
	400	425.0	376.0	100	88.5
	400	734.0	719.0	100	98.0
	400	678.0	574.0	100	84.7
	400	405.0	365.0	100	90.1

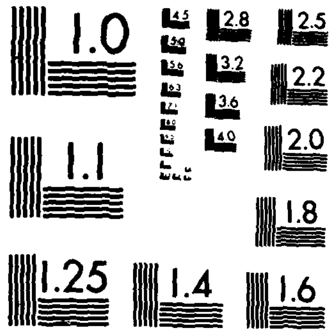
1985

Base	AGGREGATE(Asphalt Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
Andersen	400	745.0	717.0	100	96.2
	400	377.0	363.0	100	96.3
	400	450.0	309.0	100	68.7
Blythe-	400	209.0	134.0	60	64.1
ville	400	234.0	140.0	60	59.8
Vanden-	400	374.0	-	60	67.0
berg	400	401.0	-	60	41.0
	400	697.0	244.0	60	35.0
	400	638.0	365.0	60	57.2
	400	364.0	244.0	60	67.0
Andersen	400	343.0	332.0	100	96.8
	400	358.0	267.0	100	74.6
	400	298.0	157.0	100	52.7
	400	252.0	143.0	100	56.7
	400	340.0	224.0	100	65.9
	400	383.0	325.0	100	84.9
	400	337.0	292.0	100	86.6
	400	272.0	244.0	100	89.7
	400	400.0	397.0	100	99.3
	400	320.0	310.0	100	96.9
	400	385.0	381.0	100	99.0
	400	436.0	386.0	100	88.5
	400	779.0	721.0	100	92.6
	400	412.0	378.0	100	91.7
	400	327.0	245.0	100	74.9
	400	367.0	341.0	100	92.9
	400	382.0	299.0	100	78.3
	400	293.0	255.0	100	87.0
	400	350.0	289.0	100	82.6
	400	363.0	305.0	100	84.0
	400	327.0	261.0	100	79.8
	400	546.0	418.0	100	76.6
	400	425.0	357.0	100	84.0
	400	492.0	383.0	100	77.8
	400	451.0	318.0	100	70.5
	400	506.0	422.0	100	83.4
	400	397.0	279.0	100	70.3
	700	448.0	438.0	60	97.8
	700	384.0	383.0	60	99.7
	700	512.0	453.0	60	88.5
	700	339.0	257.0	60	75.8
	700	472.0	242.0	60	51.3
	700	519.0	273.0	60	52.6
	700	504.0	250.0	60	49.6
	700	545.0	295.0	60	65.0
	700	300.0	297.0	60	99.0
	700	432.0	432.0	60	100.0

1985

Base	AGGREGATE (Asphalt Bitumen) Quantity (lbs/sq) Required	Actual	Embedment Actual (lbs/sq)	Embedment (%) Required	Actual
Andersen	700	533.0	533.0	60	100.0
	700	481.0	428.0	60	89.0
	700	427.0	424.0	60	99.3
	700	494.0	362.0	60	73.3
	700	560.0	560.0	60	100.0
	700	709.0	709.0	60	100.0
	700	543.0	430.0	60	79.2
	700	336.0	281.0	60	83.6
	700	404.0	404.0	60	100.0
	700	331.0	179.0	60	54.1
	700	319.0	311.0	60	97.5
	700	255.0	241.0	60	94.5
	700	360.0	339.0	60	94.2
	700	416.0	355.0	60	85.3
	700	493.0	485.0	60	98.4
	700	377.0	177.0	60	46.9
	700	437.0	381.0	60	87.2
	700	439.0	367.0	60	83.6
	700	612.0	598.0	60	97.7
	700	605.0	587.0	60	97.0
	700	538.0	520.0	60	96.7
	700	654.0	611.0	60	93.4
	700	699.0	-	60	93.0
	700	775.0	-	60	94.0
	400	319.0	159.0	100	49.8
	400	411.0	187.0	100	45.5
	400	341.0	189.0	100	55.4
	400	367.0	308.0	100	83.9
	400	441.0	340.0	100	77.1
	400	396.0	176.0	100	44.4
	400	352.0	348.0	100	98.9
	400	416.0	289.0	100	69.5
	400	372.0	158.0	100	42.4
	400	361.0	259.0	100	71.7
	400	475.0	280.0	100	58.9
	400	317.0	247.0	100	77.9
	400	397.0	277.0	100	69.8
	400	406.0	387.0	100	95.3
	400	452.0	422.0	100	93.4
	400	273.0	239.0	100	87.5
	400	372.0	365.0	60	98.1
	400	371.0	353.0	100	95.1
	400	455.0	429.0	100	94.3
	400	389.0	296.0	100	76.1
	400	283.0	255.0	100	90.1
	400	406.0	321.0	100	79.1
	400	448.0	387.0	100	86.4

AD-A174 539 INVESTIGATION OF AIR FORCE BUILD-UP ROOFING TOLERANCES 3/3
(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH
SCHOOL OF SYSTEMS AND LOGISTICS D R LAVIGNE SEP 86
UNCLASSIFIED AFIT/GEM/DET/86S-16 F/G 13/13 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

1985

Base	AGGREGATE(Asphalt Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
Anderson	400	438.0	331.0	100	75.6
	400	372.0	369.0	100	99.2
	400	455.0	434.0	100	95.4
	400	409.0	396.0	100	96.8
	400	541.0	536.0	100	99.1
	400	348.0	283.0	100	81.3
	400	293.0	280.0	100	95.6
	400	438.0	410.0	100	93.6
	400	378.0	374.0	100	98.9
	400	327.0	207.0	100	63.3
	400	414.0	293.0	100	70.8
	400	460.0	379.0	100	82.4
	400	664.0	612.0	100	92.2
	400	432.0	305.0	100	70.6
	400	534.0	350.0	100	65.5
	400	615.0	429.0	100	69.8
	400	551.0	427.0	100	77.5
	400	531.0	376.0	100	70.8
	400	415.0	415.0	100	100.0
	400	531.0	489.0	100	92.1
	700	570.0	531.0	60	93.2
	700	629.0	591.0	60	94.0
	700	633.0	602.0	60	95.1
	700	670.0	546.0	60	81.5
	700	635.0	591.0	60	93.1
	400	618.0	-	60	100.0
	400	1161.0	-	60	100.0
	400	507.0	-	60	100.0
	400	504.0	-	60	100.0
	400	442.0	-	60	100.0
	400	639.0	-	60	100.0
	400	857.0	-	60	84.0
	400	519.0	-	60	100.0
	400	730.0	-	60	100.0
	400	575.0	-	60	100.0
	400	699.0	-	60	100.0
	400	707.0	-	60	100.0
	700	266.0	259.0	60	97.4
	700	402.0	379.0	60	94.3
	700	545.0	474.0	60	87.0
Platts-burgh	400	511.0	271.0	60	53.0
	400	564.0	345.0	60	61.2
	400	530.0	305.0	60	57.5
	400	372.0	219.0	60	53.9
	400	474.0	230.0	60	48.5
	400	478.0	317.0	60	66.3
	400	368.0	240.0	60	65.2

1985

Base	AGGREGATE(Asphalt Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
Platts-burgh	400	513.0	351.0	60	68.4
	400	445.0	279.0	60	62.7
	400	527.0	391.0	60	74.2
	400	407.0	288.0	60	70.8
	400	467.0	410.0	60	87.8
	400	534.0	366.0	60	68.5
Griffiss	400	486.0	203.0	60	41.8
	400	465.0	64.0	60	13.8
	400	480.0	33.0	60	6.9
	400	617.0	328.0	60	53.2
	400	496.0	225.0	60	45.4
	400	719.0	329.0	60	45.8
	400	530.0	288.0	60	54.3
	400	608.0	261.0	60	42.9
	400	644.0	276.0	60	42.9
	400	764.0	394.0	60	51.6
	400	571.0	468.0	60	82.0
	400	486.0	377.0	60	77.6
	400	298.0	27.0	60	9.1
	400	586.0	514.0	60	87.1
	400	312.0	108.0	60	34.6
	400	365.0	69.0	60	18.9
	400	420.0	216.0	60	51.4
	400	330.0	163.0	60	49.4
	400	428.0	237.0	60	55.4
	400	429.0	231.0	60	53.4
	400	326.0	110.0	60	33.7
	400	283.0	123.0	60	43.5
	400	445.0	228.0	60	51.2
	400	516.0	326.0	60	63.3
	400	343.0	137.0	60	39.9
	400	440.0	208.0	60	47.3
	400	530.0	246.0	60	46.4
	400	530.0	223.0	60	42.1
	400	423.0	97.0	60	22.9
	400	431.0	146.0	60	33.9
	400	589.0	269.0	60	45.7
	400	581.0	299.0	60	51.5
	400	616.0	257.0	60	41.7
	400	411.0	190.0	60	46.2
	400	362.0	109.0	60	30.1
	400	376.0	128.0	60	34.0
	400	334.0	30.0	60	9.0
	400	192.0	190.0	60	99.0
	400	266.0	262.0	60	98.5
	400	458.0	252.0	60	55.0
	400	344.0	162.0	60	47.1

1985

Base	AGGREGATE(Asphalt Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
Griffiss	400	306.0	113.0	60	36.9
	400	362.0	267.0	60	73.8
	400	447.0	169.0	60	37.8
	400	390.0	63.0	60	16.2
Vanden-	500	547.0	-	60	100.0
berg	500	347.0	-	60	100.0
	500	373.0	-	60	100.0
	500	470.0	-	60	100.0
	500	377.0	-	60	100.0
	500	394.0	-	60	100.0
	500	298.0	-	60	100.0
	500	516.0	-	60	100.0
	500	397.0	-	60	100.0
	500	376.0	-	60	100.0
	500	548.0	-	60	100.0
	500	376.0	-	60	100.0
	500	378.0	-	60	100.0
	500	349.0	-	60	100.0
	500	340.0	-	60	100.0
	500	421.0	-	60	100.0
	400	429.0	219.0	60	51.4
	400	425.0	187.0	60	44.0
	400	492.0	296.0	60	60.2
March	400	309.1	221.7	100	71.7
	400	453.4	355.8	100	78.5

E. Coal Tar Sample Data

COAL TAR 1982

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Blythe-ville	75	42.4	25	23.9	2.3
	150	93.0	25	21.6	0.0
	150	204.4	25	24.8	1.8
	75	132.4	25	24.8	1.4
	75	120.9	25	22.7	2.2
	75	111.4	25	23.8	1.2
	75	98.1	25	24.7	1.6
	75	131.5	25	21.3	0.9
	75	98.5	25	21.1	1.6
	75	144.7	25	37.0	2.4
	75	99.2	25	31.6	2.3
	75	50.3	25	36.1	0.0
	75	64.0	25	31.1	5.4
Bolling	-	50.6	25	42.2	1.8
	-	29.8	25	27.4	3.1
	-	20.8	25	26.8	2.5
	-	23.7	25	24.7	2.3
	-	21.2	25	23.9	2.6
	-	18.4	25	35.3	1.7
	-	34.4	25	22.0	1.2
	-	26.4	25	30.0	1.2
	-	18.7	25	24.0	0.6
Pitts-burgh	75	70.3	25	24.9	3.8
	75	75.0	25	35.5	3.8
	75	70.2	25	23.6	4.2
	75	84.7	25	28.4	4.9
	75	40.9	25	31.0	3.6
	75	66.7	25	25.6	4.3
	75	81.3	25	24.6	1.9
	75	109.8	25	26.3	4.2
	75	159.0	25	30.9	4.2
	75	118.5	25	34.3	3.9
	75	142.9	25	34.3	3.8
Unknown	75	97.4	25	38.5	1.8
	75	66.9	25	24.2	1.9
	70	67.2	20	24.7	2.1
	70	88.1	20	30.4	2.4
	70	62.6	20	35.7	2.0
	70	32.3	20	28.4	3.0

COAL TAR 1983

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Griffiss	75	66.2	25	28.0	1.4
	75	78.5	25	25.7	2.1
	75	70.8	25	20.6	0.2
	75	73.6	25	28.1	2.0
	75	77.0	25	25.4	1.1
Barksdale	75	58.1	30	31.8	2.9
	75	66.4	30	27.3	-
	75	53.7	30	26.1	3.2
	75	69.7	30	27.7	3.2
	75	66.2	30	35.3	3.3
	75	74.3	30	29.0	3.9
Richards-	75	66.8	25	22.5	2.8
Gebaur	75	64.3	25	27.7	0.2
	75	88.6	25	32.2	0.0
	75	59.0	25	30.3	0.0
	75	76.9	25	23.9	2.1
	75	72.2	25	41.3	-
Little	75	314.0	25	19.3	1.8
Rock	75	199.0	25	22.0	1.8
	75	210.0	25	24.1	1.9
	75	262.0	25	26.1	2.3
	75	186.0	25	25.0	1.2
	75	185.0	25	25.3	1.6
	75	223.0	25	33.0	1.5
	75	198.0	25	25.8	1.9
	75	215.0	25	23.3	1.2
	75	31.0	25	29.3	1.4
	75	70.0	25	39.0	1.3
Unknown	75	48.6	25	29.1	0.4
	75	80.7	25	33.2	2.6
	75	73.5	25	27.9	3.1
	75	66.8	25	27.4	3.8
	75	31.7	25	44.0	3.5
	75	52.7	25	36.3	1.5
	70	87.3	20	29.0	2.6
	70	70.8	20	28.8	2.4
	70	56.9	20	21.0	1.6
	70	74.4	20	25.3	2.5
	70	81.1	20	22.9	2.0
	70	80.6	20	35.1	1.8
	70	94.1	20	19.7	2.3
	70	77.3	20	25.9	2.6
	7C	81.2	20	22.5	3.1
	70	80.0	20	28.4	3.6
	70	83.5	20	18.4	2.3
	70	82.4	20	24.2	2.9
	70	78.6	20	25.0	2.1
	70	77.2	20	23.9	1.5

COAL TAR 1983

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Unknown	70	68.5	20	22.6	2.8
	70	77.1	20	20.2	0.0
	70	65.5	20	22.6	2.8
	70	90.0	20	21.5	0.5
	70	70.5	20	27.7	0.6
	70	58.5	20	26.5	2.2
	70	91.1	20	24.5	2.1
	70	71.9	20	29.8	1.5
	70	66.2	20	22.7	1.8
	70	61.3	20	27.2	2.2
	70	79.6	20	29.5	1.8
	70	65.5	20	28.1	1.5
	70	59.8	20	27.5	1.5
	70	74.4	20	40.9	1.5
	70	78.4	20	22.7	1.5
	70	76.4	20	19.8	2.1
	70	67.4	20	19.9	2.4
	70	97.3	20	19.8	2.0
	70	71.6	20	21.2	1.5
	70	65.7	20	27.0	2.0
	70	62.4	20	29.1	1.6
	70	65.2	20	25.1	2.1
	70	76.2	20	26.2	1.3
	70	83.1	20	25.6	1.4
	70	69.3	20	28.3	1.8
	70	85.6	20	29.3	1.8
	70	88.1	20	28.7	2.0
	70	55.0	20	25.3	0.8
	70	66.7	20	28.1	1.6
	70	66.3	20	22.9	2.1
	70	52.3	20	25.9	3.0
	70	67.7	20	32.5	1.4
	70	85.6	20	29.4	0.0
	70	88.0	20	30.7	1.4
	70	88.1	20	30.7	1.4
	70	97.8	20	31.6	3.4
	70	97.8	20	31.6	3.4
	70	72.1	20	21.4	1.6
	70	77.3	20	22.3	1.9
	70	43.2	20	26.8	2.0
	70	70.7	20	31.2	1.3
	70	62.8	20	30.2	2.8
	70	64.7	20	34.2	0.5
	70	75.5	20	24.7	3.8
	70	79.1	20	30.5	2.4
	70	62.3	20	27.9	2.4
	70	71.9	20	36.2	1.3
	70	66.6	20	22.0	2.5

COAL TAR 1983

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Unknown	70	93.3	20	30.3	2.3
	70	41.3	20	23.9	2.8
	70	-	20	19.6	2.6
	70	79.7	20	27.5	1.8
	70	88.8	20	33.9	2.9
	70	42.1	20	33.9	2.3
	70	64.8	20	32.9	2.4
	70	73.7	20	32.3	1.1
	70	90.8	20	30.2	2.0
	70	67.1	20	44.4	3.1
	70	56.4	20	34.8	2.0
	70	59.3	20	25.6	2.1
	70	68.2	20	31.1	1.9
	70	73.1	20	34.2	2.0
	70	79.5	20	32.8	1.6
	70	65.9	20	18.5	0.0
	70	63.0	20	18.5	0.0
	70	60.3	20	18.0	1.9
	70	32.9	20	22.2	1.9
	70	71.2	20	17.2	1.8
	70	41.4	20	39.4	3.1
	70	35.2	20	23.0	1.3
	70	36.7	20	19.6	1.8
	70	41.5	20	33.0	2.3
	70	24.2	20	21.5	1.8
	70	82.2	20	30.0	1.9
	70	83.5	20	28.0	2.6
	70	70.1	20	33.8	3.0
	70	41.4	20	25.2	2.8

COAL TAR 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Dover	75	154.2	25	30.4	1.2
	75	119.6	25	34.2	1.3
	75	58.8	25	21.4	2.4
	75	74.0	25	28.5	1.5
	75	129.4	25	27.9	0.9
	75	70.4	25	33.9	7.6
	75	68.2	25	26.4	2.1
	75	120.3	25	30.7	0.2
	75	229.3	25	44.1	1.8
Maxwell	75	131.9	25	27.4	1.4
	75	128.6	25	38.5	1.6
	75	110.8	25	32.4	1.2
	75	145.8	25	25.5	1.3
	75	57.5	25	19.8	1.8
	75	97.1	25	31.4	1.6
	75	89.9	25	21.6	1.3
	75	93.3	25	26.5	1.9
	75	92.1	25	31.9	2.5
	75	84.2	25	19.4	2.4
	75	74.4	25	22.7	1.9
	75	80.6	25	26.4	2.1
Dover	75	101.8	25	37.6	1.8
	75	242.4	25	27.4	3.7
	75	65.8	25	25.3	1.4
Little Rock	75	90.0	25	36.8	1.5
	75	79.0	25	34.8	2.2
	75	97.0	25	33.5	0.9
	75	126.0	25	37.4	-
	75	105.0	25	35.6	2.4
	75	110.0	25	38.0	1.1
	75	170.0	25	21.0	1.6
	75	115.0	25	33.8	1.9
	75	68.0	25	25.3	-0.6
	75	39.0	25	36.5	3.2
	75	46.0	25	31.5	1.7
	75	133.0	25	36.5	2.2
	75	138.0	25	32.0	1.3
	75	109.0	25	26.5	1.9
	75	115.0	25	37.8	1.6
Loring	75	124.0	25	22.6	0.0
	75	82.0	25	29.4	3.3
	75	47.0	25	18.0	1.8
	75	30.0	25	22.3	1.9
	75	51.0	25	20.0	0.0
	75	23.0	25	29.4	-
	75	46.0	25	21.3	0.2
	75	64.0	25	28.0	3.0
	75	29.0	25	33.3	2.5
	75	30.0	25	24.0	2.1

COAL TAR 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
McConnell	75	61.0	30	27.8	2.3
	75	63.0	30	23.0	1.8
	75	79.0	30	23.5	-
	75	142.0	30	29.7	2.1
	75	60.0	30	30.5	2.2
	75	59.0	30	23.8	2.0
	75	60.0	30	33.5	-
	75	64.0	30	26.3	1.7
	75	84.0	30	31.0	3.6
	75	75.0	30	31.0	3.3
	75	98.0	30	31.3	0.7
	75	147.0	30	40.0	4.8
	75	52.0	30	38.9	3.5
	75	60.0	30	30.8	1.9
	75	54.0	30	26.0	1.8
Andersen	75	162.0	25	25.5	0.8
	75	123.0	25	26.8	0.8
	75	145.0	25	26.8	0.0
	75	124.0	25	28.8	2.2
	75	154.0	25	28.5	3.5
	75	149.0	25	25.3	1.6
	75	181.0	25	25.8	1.1
	75	213.0	25	32.5	2.7
	75	101.0	25	27.3	2.5
	75	219.0	25	26.3	1.7
	75	127.0	25	25.5	1.7
	75	229.0	25	32.8	1.8
	75	174.0	25	28.0	1.6
	75	153.0	25	31.4	2.2
	75	136.0	25	31.9	2.9
	75	184.0	25	27.3	1.6
	75	204.0	25	29.0	1.4
	75	197.0	25	29.3	1.7
	75	207.0	25	26.7	2.3
	75	209.0	25	27.5	1.2
	75	136.0	25	28.5	2.3
	75	217.0	25	26.0	1.0
	75	55.0	25	30.9	1.4
	75	244.0	25	35.4	-
	75	146.0	25	20.8	1.4
	75	167.0	25	32.1	-
	75	116.0	25	21.8	0.8
	75	245.0	25	24.5	2.1
	75	239.0	25	21.0	1.5
	75	139.0	25	23.0	0.9
	75	210.0	25	30.3	2.0
	75	335.0	25	28.0	1.5
	75	349.0	25	17.3	1.5

COAL TAR 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Andersen	75	226.0	25	21.0	1.7
	75	338.0	25	25.8	1.5
	75	166.0	25	33.3	1.6
	75	184.0	25	25.8	0.9
Griffiss	160	279.0	25	26.3	2.1
	160	268.0	25	22.8	1.7
	160	205.0	25	24.3	1.5
	160	115.0	25	24.8	1.4
	160	121.0	25	23.5	4.1
	60	115.0	30	24.8	1.4
	60	121.0	30	23.5	4.1
	160	65.0	25	25.3	1.7
Unknown	75	81.9	25	20.8	1.9
	75	56.6	25	26.0	1.8
	75	60.1	25	27.2	2.4
	75	72.9	25	20.2	1.9
	75	78.6	25	26.8	1.5
	75	72.3	25	26.0	1.5
	75	98.9	25	31.1	2.3
	75	92.7	25	21.6	2.3
	75	78.2	25	28.9	1.1
	75	77.8	25	22.4	2.5
	75	72.3	25	28.2	2.3
	75	65.0	25	27.1	2.1
	75	83.9	25	17.3	2.1
	75	48.2	25	22.8	1.8
	75	57.3	25	24.6	1.5
	75	65.0	25	26.7	2.8
	75	50.9	25	25.0	1.9
	75	65.5	25	27.5	1.9
	75	66.7	25	22.3	2.0
	75	61.2	25	26.1	2.5
	75	77.6	25	23.8	1.9
	75	57.5	25	26.8	2.5
	75	72.7	25	25.5	1.5
	75	46.7	25	25.5	2.6
	75	56.0	25	32.8	2.3
	75	65.0	25	29.1	1.5
	75	33.7	25	31.1	2.8
	75	36.8	25	25.2	2.5
	75	67.7	25	21.6	1.9
	75	70.5	25	24.0	1.8
	75	68.3	25	24.5	2.3
	70	71.4	20	34.4	4.3
	70	60.6	20	22.7	1.9
	70	78.5	20	26.8	2.3
	70	64.7	20	30.1	2.0
	70	90.6	20	31.1	2.3
	70	67.7	20	32.7	1.8

COAL TAR 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Unknown	70	69.6	20	25.1	1.9
	70	72.4	20	31.0	2.0
	70	94.2	20	35.5	2.0
	70	73.5	20	28.7	2.0
	70	99.5	20	34.8	2.0
	70	85.4	20	36.7	2.4
	70	85.2	20	35.7	2.0
	70	97.0	20	36.6	2.3
	70	84.0	20	37.2	2.4
	70	91.9	20	32.8	1.9
	70	90.3	20	27.7	2.0
	75	58.4	25	31.3	2.3
	75	59.6	25	30.0	2.3
	75	52.1	25	27.6	2.1
	75	66.4	25	29.0	2.3
	75	64.4	25	28.7	1.3
	75	72.0	25	33.6	2.3
	75	97.5	25	40.2	3.0
	75	64.0	25	32.4	2.5
	75	69.7	25	33.7	1.6
	75	54.6	25	32.5	2.1
	75	55.0	25	29.9	1.4
	75	64.5	25	26.2	3.0
	75	60.5	25	25.9	1.1
	75	55.5	25	28.2	2.4
	75	49.6	25	29.1	3.0
	75	58.6	25	26.4	2.4
	75	47.2	25	28.2	2.0
	75	59.3	25	21.2	2.1
	75	52.6	25	32.5	2.1
	75	42.7	25	21.3	1.6
	75	83.3	25	25.6	1.5
	75	69.8	25	30.1	2.0
	75	66.7	25	33.2	2.3
	75	65.2	25	20.6	2.9
	75	80.7	25	41.3	2.8
	75	51.3	25	29.8	4.9
	75	57.5	25	23.7	3.0
	75	100.0	25	27.8	4.4
	75	92.0	25	30.0	2.6
	75	75.6	25	34.3	2.0
	75	76.1	25	25.7	3.8
	75	68.3	25	32.5	1.3
	75	78.3	25	35.4	3.3
	75	97.5	25	30.5	2.9
	75	83.0	25	27.9	1.0
	75	54.0	25	29.2	2.0
	75	79.5	25	29.4	1.6

COAL TAR 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Unknown	75	84.6	25	29.4	2.5
	75	68.5	25	36.7	3.3
	75	92.3	25	42.6	3.6
	75	69.7	25	25.9	3.1
	75	95.2	25	41.1	2.0
	75	97.8	25	32.3	1.1
	75	79.0	25	31.9	2.0
	75	79.6	25	26.6	2.5
	75	60.4	25	25.8	1.6
	75	76.6	25	29.9	2.3
	75	65.6	25	29.4	2.0
	75	79.6	25	32.1	2.5
	75	67.6	25	21.4	1.9
	75	63.7	25	29.5	0.3
	75	98.1	25	24.2	1.9
	75	74.7	25	32.7	1.9
	75	79.3	25	24.2	1.9
	75	60.2	25	33.2	2.1
	75	82.6	25	34.7	2.9
	75	83.7	25	36.7	2.4
	75	73.8	25	27.8	1.1
	75	66.1	25	25.2	2.4
	75	75.1	25	33.4	1.5
	75	59.1	25	34.0	2.3
	75	38.5	25	27.8	2.0
	75	49.9	25	27.0	1.5
	75	63.4	25	28.6	1.5
	75	63.8	25	22.8	1.8
	75	67.1	25	28.6	1.8
	75	45.2	25	28.3	2.8
	75	65.0	25	24.8	2.0
	75	62.6	25	26.9	1.8
	75	56.0	25	28.4	1.4
	75	70.5	25	32.9	1.6
	75	48.4	25	25.0	1.5
	75	41.4	25	27.3	1.8
	75	45.5	25	21.2	1.6
	75	89.1	25	26.8	2.1
	75	70.8	25	31.0	1.9
	75	67.0	25	31.3	1.4
	75	63.0	25	24.0	1.4
	75	75.4	25	32.1	1.8
	75	89.0	25	31.8	1.6
	75	92.6	25	26.9	2.0
	75	66.7	25	27.1	2.3
	75	81.3	25	35.4	2.0
	75	84.7	25	26.5	2.1
	75	64.2	25	28.1	1.9

COAL TAR 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Unknown	75	88.8	25	29.6	1.3
	75	46.6	25	28.8	2.1
	75	91.1	25	31.3	2.4
	75	45.6	25	31.2	2.1
	75	62.8	25	32.5	2.5
	75	85.7	25	26.6	1.8
	75	45.6	25	30.4	2.6
	75	65.9	25	28.4	1.9
	75	66.1	25	25.6	1.8
	75	63.7	25	27.2	1.3
	75	76.9	25	28.6	1.4
	75	72.3	25	27.5	2.4
	75	47.3	25	26.4	2.0
	75	60.2	25	21.5	1.8
	75	68.0	25	31.7	1.8
	75	60.9	25	22.8	2.5
	75	82.4	25	25.3	1.8
	75	77.4	25	31.1	2.0
	75	57.9	25	29.2	2.0
	75	53.9	25	24.4	2.1
	75	62.3	25	30.0	2.0
	75	46.1	25	19.9	1.9
	75	53.3	25	25.1	1.8
	75	56.3	25	28.0	1.5
	75	99.3	25	30.2	2.4
	75	61.1	25	25.1	2.1
	75	51.0	25	32.1	2.5
	75	72.1	25	29.9	2.3
	75	69.1	25	29.1	1.8
	75	75.7	25	23.6	2.3
	75	93.3	25	26.7	2.4
	75	83.3	25	32.0	1.8
	75	95.2	25	28.4	2.8
	75	64.5	25	27.9	1.8
	75	68.3	25	32.4	2.0
	75	98.7	25	25.0	2.5
	75	89.3	25	26.7	2.0
	75	85.1	25	27.2	1.8
	75	94.9	25	29.0	2.3
	75	96.7	25	24.5	2.0
	75	61.9	25	28.7	2.0
	75	69.4	25	21.8	1.4
	75	76.8	25	21.0	1.6
	75	94.0	25	29.8	0.6
	75	69.8	25	22.7	0.0
	75	62.8	25	31.4	1.1
	75	73.6	25	28.6	3.6
	75	99.8	25	25.9	0.0

COAL TAR 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Unknown	75	96.3	25	21.5	1.9
	75	65.8	25	20.6	1.4
	75	72.1	25	26.0	1.5
	75	97.0	25	27.0	1.0
	75	78.1	25	24.9	1.6
	75	84.7	25	26.0	1.0
	75	84.4	25	18.8	2.0
	75	84.3	25	24.8	1.3
	75	63.0	25	33.8	2.0
	75	61.9	25	25.7	2.0
	75	91.5	25	24.6	4.3
	75	68.0	25	19.1	1.5
	75	58.9	25	28.2	2.0
	75	66.2	25	30.4	2.0
	75	53.3	25	18.3	2.0
	75	60.6	25	21.7	0.0
	75	82.4	25	28.6	1.8
	75	81.9	25	23.8	1.5
	75	78.9	25	28.7	1.9
	75	94.5	25	24.3	1.3
	75	81.6	25	21.6	2.8
	75	87.4	25	33.0	1.6
	75	98.2	25	28.5	4.5
	75	44.8	25	32.6	1.3
	75	29.9	25	31.9	1.0
	75	69.3	25	32.9	1.0
	75	87.1	25	27.7	2.4
	75	94.8	25	35.7	1.9
	75	76.6	25	28.8	2.1
	75	74.6	25	27.6	2.0
	75	84.8	25	34.0	2.0
	75	64.8	25	33.4	2.6
	75	66.6	25	28.3	2.3
	75	70.5	25	31.3	3.3
	75	67.8	25	32.7	2.3
	75	60.8	25	29.9	1.9
	75	60.0	25	25.8	2.3
	75	83.5	25	34.6	1.9
	75	64.5	25	28.0	2.3
	75	100.0	25	36.2	2.5
	75	80.6	25	27.7	2.3
	75	71.6	25	27.2	2.0
	75	85.6	25	33.3	2.4
	75	67.4	25	28.7	2.3
	75	91.6	25	30.4	2.0
	75	67.9	25	25.2	2.3
	75	88.0	25	28.5	2.0
	75	84.1	25	30.3	2.5

COAL TAR 1984

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Unknown	75	85.2	25	30.4	2.5
	75	82.6	25	21.3	2.3
	75	54.4	25	21.5	2.1
	75	80.8	25	28.2	2.3
	75	69.2	25	30.3	2.1
	75	69.5	25	34.2	2.0
	75	61.7	25	28.6	2.4
	75	84.7	25	34.5	2.0
	75	58.6	25	30.9	1.9
	75	65.3	25	22.8	2.1
	75	48.5	25	23.0	2.0
	75	67.2	25	32.7	2.1
	75	51.7	25	25.2	1.6
	75	59.8	25	21.6	1.4
	75	53.3	25	20.9	2.0
	75	46.9	25	31.6	0.0
	75	48.1	25	22.7	1.8
	75	58.3	25	33.6	2.0
	75	52.1	25	25.8	2.1
	75	77.4	25	36.0	1.9
	75	68.7	25	31.8	2.3
	75	84.6	25	38.4	5.5
	75	71.1	25	34.0	2.1
	75	72.3	25	35.0	2.3
	75	63.4	25	29.6	2.3
	75	60.6	25	31.2	1.9
	75	71.5	25	34.4	2.5
	75	72.2	25	29.7	2.1
	75	33.8	25	21.6	2.8
	75	81.6	25	22.7	2.8
	70	85.1	20	27.2	1.8

COAL TAR 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
O'Hare	70	34.4	20	30.9	1.6
	70	44.8	20	34.6	2.9
	70	69.3	20	34.4	1.9
	70	80.9	20	33.2	2.1
	70	74.8	20	26.9	4.0
	70	79.0	20	18.3	0.9
	70	74.0	20	32.7	2.4
	70	83.8	20	28.2	1.8
	70	70.6	20	29.1	3.9
	70	97.4	20	23.5	2.2
	70	74.0	20	25.4	1.2
	70	72.4	20	31.7	2.8
	70	65.3	20	32.2	2.6
	70	88.2	20	27.5	3.4
	70	76.3	20	29.4	3.6
	70	128.0	20	39.4	3.1
	70	161.7	20	31.0	6.7
	70	105.2	20	33.7	1.2
	70	174.5	20	33.8	4.0
Bolling	75	-	30	34.5	2.0
	75	-	30	29.5	2.2
	75	-	30	29.9	2.3
Dover	70	143.3	20	28.7	3.7
	70	137.6	20	21.8	-
	70	132.8	20	23.5	-
	70	179.6	20	26.2	1.9
Richard	60	88.4	20	22.0	1.8
Gebaur	60	86.5	20	20.4	7.9
	60	85.0	20	32.9	1.9
	60	95.1	20	23.3	1.9
Platts-	75	61.0	25	23.3	1.0
burgh	75	110.0	25	21.2	1.8
	75	65.0	25	17.7	1.3
	75	95.0	25	20.3	1.6
Vandenberg	75	148.0	30	27.6	2.4
Unknown	75	65.7	25	29.6	2.0
	75	58.1	25	21.3	1.9
	75	82.2	25	27.3	3.1
	75	45.7	25	25.9	2.5
	75	97.2	25	19.8	2.5
	75	55.8	25	34.0	3.3
	75	68.0	25	23.6	2.0
	75	94.5	25	24.1	2.8
	75	77.6	25	30.8	1.8
	75	34.7	25	28.5	0.0
	75	39.5	25	22.8	1.8
	75	89.0	25	27.4	1.8
	75	95.6	25	20.5	1.8

COAL TAR 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Unknown	75	25.5	25	26.6	0.0
	75	68.4	25	21.1	2.3
	75	53.6	25	25.3	0.9
	75	41.4	25	29.5	2.1
	75	43.9	25	25.3	0.0
	75	45.6	25	23.0	0.0
	75	46.9	25	21.7	1.8
	75	27.0	25	23.3	0.1
	75	58.6	25	29.6	2.6
	75	27.9	25	33.0	0.0
	75	47.2	25	25.5	1.8
	75	49.0	25	18.1	2.3
	75	53.1	25	18.4	1.8
	75	90.7	25	35.8	2.1
	75	81.1	25	31.7	1.8
	75	71.9	25	27.3	2.0
	75	90.8	25	22.6	2.8
	75	90.8	25	25.9	0.0
	75	57.7	25	31.0	2.4
	75	90.4	25	30.7	2.1
	75	61.7	25	31.8	1.5
	75	50.4	25	38.1	2.5
	75	80.4	25	32.3	2.3
	75	80.2	25	28.7	2.3
	75	82.4	25	36.8	2.4
	75	56.0	25	31.0	2.3
	75	94.8	25	34.0	2.1
	75	46.2	25	25.0	2.4
	75	66.3	25	23.6	2.9
	75	74.0	25	27.6	2.3
	75	74.0	25	42.7	2.4
	75	84.2	25	30.6	2.8
	75	67.9	25	34.4	2.1
	75	55.3	25	27.4	2.1
	75	69.4	25	33.5	2.5
	75	54.5	25	32.7	0.0
	75	66.7	25	29.6	2.9
	75	42.3	25	29.6	2.3
	75	72.8	25	33.4	2.3
	75	69.1	25	34.4	2.3
	75	68.1	25	29.1	2.1
	75	62.1	25	35.8	1.3
	75	75.2	25	29.9	2.5
	75	60.6	25	40.0	2.0
	75	82.6	25	34.1	2.8
	75	-	25	35.3	1.5
	75	74.5	25	25.8	1.5
	75	97.5	25	24.6	1.8

COAL TAR 1985

BASE	FLOOD(lbs/sq) REQUIRED	FLOOD(lbs/sq) ACTUAL	INTERPLY(lbs/sq) REQUIRED	INTERPLY(lbs/sq) ACTUAL	HEADLAP(inch) ACTUAL
Unknown	75	60.6	25	22.5	2.1
	75	91.8	25	22.0	2.1
	75	78.5	25	35.8	2.0
	75	83.1	25	34.8	3.4
	75	62.6	25	27.5	1.5
	75	91.1	25	24.6	2.5
	75	88.3	25	34.7	0.0
	75	81.2	25	31.8	1.4
	75	65.5	25	33.1	7.8
	75	44.9	25	32.4	0.0
	75	47.5	25	25.7	1.3
	75	46.9	25	38.8	3.9
	75	57.5	25	31.0	1.6
	75	46.5	25	27.5	2.0
	75	59.2	25	32.2	2.5
	75	75.7	25	40.8	2.0
	75	92.9	25	18.3	2.3
	75	63.1	25	18.9	2.0
	75	42.7	25	16.3	2.3
	75	97.9	25	25.2	2.4
	75	96.6	25	22.6	2.3
	75	92.4	25	26.8	5.0
	75	54.7	25	34.3	2.3
	75	22.5	25	21.4	2.3
	75	50.7	25	23.1	2.3
	75	67.5	25	26.0	1.6
	75	58.7	25	34.5	2.8
	75	79.4	25	32.0	0.0
	75	99.6	25	26.7	2.8
	75	62.9	25	34.9	2.5
	75	42.1	25	27.0	1.9
	75	-	25	33.7	1.9
	75	-	25	30.4	2.3
	75	-	25	25.9	2.6
	75	-	25	30.1	3.0
	75	66.5	25	28.0	2.6
	75	-	25	25.9	2.0
	75	-	25	25.7	2.0
	75	-	25	23.8	1.5
	75	68.2	25	38.4	0.0
	75	-	25	27.0	1.0
	75	-	25	26.7	2.3
	75	67.2	25	25.2	2.3
	75	-	25	23.7	1.8
	70	70.5	20	29.6	2.9

1982

AGGREGATE(Coal Tar Bitumen)

Base	Quantity(lbs/sq) Required	Quantity(lbs/sq) Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Embedment(%) Actual
Blythe-ville	400	246.4	178.3	60	72.4
	700	269.9	241.3	60	89.4
	400	508.2	497.6	60	98.0
	400	406.5	395.4	60	97.3
	400	327.0	301.9	60	92.3
	400	323.6	300.0	60	92.7
	400	336.9	291.0	60	86.4
	400	413.8	389.8	60	94.2
	400	381.1	298.8	60	78.4
	400	473.4	335.1	60	70.8
	400	309.6	186.5	60	60.2
	400	247.9	132.9	60	53.6
	400	296.1	179.2	60	60.5
	400	349.1	266.8	60	76.4
Pitts-burgh PA	300	308.2	117.8	60	38.2
	300	312.0	136.0	60	43.6
	300	324.3	153.7	60	47.4
	300	378.6	253.2	60	66.9
	300	341.4	176.8	60	51.8
	300	410.8	181.6	60	44.2
	300	345.5	176.1	60	51.0
	300	356.0	156.4	60	43.9
	300	489.1	275.6	60	56.3
	300	408.4	137.7	60	33.7
	300	375.8	155.3	60	41.3

1983

Base	AGGREGATE(Coal Tar Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
Griffiss	400	449.9	-	50	-
	400	404.4	-	50	-
	400	572.8	-	50	-
	400	363.4	-	50	-
	400	922.7	-	50	-
Barksdale	400	382.6	231.8	60	60.6
	400	398.6	246.2	60	61.8
	400	353.8	243.7	60	68.9
	400	405.1	331.1	60	81.7
	400	373.1	230.0	60	61.1
	400	550.2	350.1	60	63.6
Richards	400	331.3	238.3	60	71.9
Gebaur	400	320.2	155.0	60	48.4
	400	545.8	269.2	60	49.3
	400	486.5	219.6	60	45.1
	400	480.8	197.0	60	33.9
	400	495.5	198.8	60	40.1
Little	400	799.0	-	60	76.0
Rock	400	684.0	-	60	79.0
	400	770.0	-	60	74.0
	400	800.0	-	60	80.0
	400	719.0	-	60	94.0
	400	488.0	-	60	88.0
	400	548.0	-	60	70.0
	400	791.0	-	60	82.0
	400	462.0	-	60	81.0
	400	213.0	-	60	-
	400	270.0	-	60	-

1984

AGGREGATE(Coal Tar Bitumen)

Base	Quantity(lbs/sq) Required	Quantity(lbs/sq) Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Embedment(%) Actual
Dover	700	434.0	434.0	60	100.0
	700	341.1	341.1	60	100.0
	700	235.6	235.6	60	100.0
	700	294.7	294.7	60	100.0
	700	314.7	314.7	60	100.0
	300	280.4	166.2	60	59.3
	300	510.9	269.8	60	52.8
	300	545.5	295.0	60	54.1
	300	473.7	473.7	60	100.0
	525	623.6	449.1	60	72.0
	525	1078.8	821.9	60	76.2
	525	420.0	166.7	60	39.7
Maxwell	400	540.1	361.4	60	66.9
	400	615.0	440.4	60	71.6
	400	691.2	491.6	60	71.1
	400	687.5	527.1	60	76.6
	400	474.9	329.3	60	69.3
	400	576.4	396.2	60	68.6
	400	595.8	387.2	60	65.0
	400	635.4	398.6	60	62.7
	400	588.0	417.1	60	70.9
	400	572.5	395.7	60	69.1
	400	547.0	277.4	60	50.7
	400	554.9	350.2	60	63.1
Little Rock	400	593.0	-	60	47.0
	400	379.0	-	60	26.0
	400	754.0	-	60	22.0
	400	532.0	-	60	37.0
	400	478.0	-	60	42.0
	400	733.0	-	60	46.0
	400	439.0	-	60	47.0
	400	524.0	-	60	56.0
	400	517.0	-	60	34.0
	400	448.0	-	60	25.0
	400	433.0	-	60	24.0
	400	491.0	-	60	30.0
	400	700.0	-	60	46.0
	400	619.0	-	60	43.0
	400	769.0	-	60	50.0
Loring	400	587.0	-	60	59.0
	400	844.0	-	60	37.0
	400	383.0	-	60	43.0
	400	448.0	-	60	30.0
	400	341.0	-	60	14.0
	400	241.0	-	60	17.0
	400	258.0	-	60	31.0
	400	545.0	-	60	21.0

Base	AGGREGATE(Coal Tar Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
McConnell	400	282.0	173.0	60	61.3
	400	343.0	201.0	60	58.6
	400	425.0	259.0	60	60.9
	400	312.0	312.0	60	100.0
	400	352.0	178.0	60	50.6
	400	374.0	219.0	60	58.6
	400	400.0	217.0	60	54.3
	400	387.0	230.0	60	59.4
	400	463.0	290.0	60	62.6
	400	367.0	367.0	60	100.0
	400	396.0	259.0	60	65.4
	400	535.0	411.0	60	76.8
	400	402.0	169.0	60	42.0
	400	426.0	205.0	60	48.1
	400	358.0	358.0	60	100.0
Andersen	400	333.0	-	60	92.0
	400	277.0	-	60	100.0
	400	278.0	-	60	95.0
	400	292.0	-	60	100.0
	400	380.0	-	60	100.0
	400	346.0	-	60	92.0
	400	299.0	-	60	100.0
	400	555.0	-	60	90.0
	400	406.0	-	60	84.0
	400	573.0	-	60	87.0
	400	365.0	-	60	89.0
	400	595.0	-	60	95.0
	400	511.0	-	60	86.0
	400	439.0	-	60	78.0
	400	397.0	-	60	89.0
	400	680.0	-	60	92.0
	400	674.0	-	60	100.0
	400	498.0	-	60	100.0
	400	536.0	-	60	100.0
	400	556.0	-	60	100.0
	400	481.0	-	60	87.0
	400	562.0	-	60	100.0
	400	133.0	-	60	100.0
	400	486.0	-	60	100.0
	400	321.0	-	60	100.0
	400	474.0	-	60	-
	400	377.0	-	60	84.0
	400	632.0	-	60	85.0
	400	516.0	-	60	93.0
	400	402.0	-	60	83.0
	400	695.0	-	60	90.0
	400	588.0	-	60	100.0

1984

Base	AGGREGATE(Coal Tar Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
Andersen	400	349.0	-	60	74.0
	400	472.0	-	60	94.0
	400	691.0	-	60	100.0
	400	497.0	-	60	100.0
	400	432.0	-	60	100.0
Griffiss	700	662.0	-	100	100.0
	700	429.0	-	100	100.0
	700	862.0	-	100	100.0
	700	862.0	-	100	100.0
	700	705.0	-	100	64.0
	400	862.0	-	60	100.0
	400	705.0	-	60	64.0
	700	228.0	-	100	100.0

1985

Base	AGGREGATE(Coal Tar Bitumen) Quantity(lbs/sq) Required	Actual	Embedment Actual(lbs/sq)	Embedment(%) Required	Actual
O'Hare	400	359.0	359.0	-	-
	400	336.5	336.5	-	100.0
	400	426.6	204.6	60	49.0
	400	435.9	213.9	60	49.1
	400	696.0	231.9	60	30.7
	400	672.0	199.6	60	29.7
	400	490.1	285.3	60	41.3
	400	526.6	289.6	60	55.0
	400	482.3	208.4	60	43.2
	400	660.2	250.0	60	37.8
	400	748.0	272.9	60	36.5
	400	326.6	208.6	60	63.9
	400	480.4	185.9	60	38.7
	400	475.7	305.4	60	64.2
	400	472.4	222.8	60	47.1
	400	529.4	262.7	60	49.6
	400	774.3	545.0	60	70.4
	400	604.9	306.7	60	50.7
	400	716.2	383.9	60	53.6
Dover	400	239.0	239.0	60	100.0
	400	202.0	202.0	60	100.0
	500	294.5	294.5	60	100.0
Richard	400	545.6	-	60	-
Gebaur	400	584.9	-	60	-
	400	602.2	-	60	-
	400	579.5	-	60	-
Platts-	400	464.0	243.0	60	52.4
burgh	400	529.0	287.0	60	54.3
	400	484.0	119.0	60	24.6
	400	720.0	244.0	60	33.9
Vanden-berg	400	530.0	378.0	60	71.3

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The level of construction quality required by the Air Force in Air Force Manual 91-36, Built-Up Roof Management Program, is controversial. The objective of this research is to provide information pertaining to the need for and obtainability of this quality. This is done by combining a descriptive study and a statistical analysis of historical data.

The descriptive study provides a general review of published knowledge pertaining to the use and need for built-up roofing tolerances. The study draws from formal research, international symposiums, published information from national associations, periodicals and journal, texts, government publications, and manufacturers' literature. Factors influencing performance are presented. One factor, workmanship, is especially highlighted. System performance attributes are also discussed. Although vast improvement has been realized over the past ten years, premature failure rates of 10 to 15 percent are recorded. To assist in showing the need for tolerances the main built-up roofing problems, which could create failure situations, are introduced. Finally, the study provides existing viewpoints on the use of tolerances for indicating performance ability. Also included are currently recommended rates and tolerances.

The statistical analysis shows what tolerances have been obtained in completed Air Force roofing projects. Knowing what tolerances have been obtained indicates what tolerances can be obtained. Results indicate large variability with a fairly low percentage of the samples meeting Air Force requirements.

The investigation shows the selection of realistic tolerances is difficult but their use is important. To ensure quality conformance, tolerances are recommended at levels lower than the analysis can justify. Continued research on performance requirements and statistical quality control is warranted.

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